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ABSTRACT

Presented is geological information and site descriptions for teachers to use in planning and conducting earth science field trips in Virginia. Among the topics included are: (1) Geology, Soils and Land Use in Central Virginia: (2) Using Coastal Plain Stratigraphy Near Fredericksburg, Virginia as a Teaching Tool: and (3) The Culpepper Basin of the Triassic Lowlands of Northern Virginia. Emphasis is upon geological diversity, the applications of geological knowledge, and resource use. Each of the guide's five chapters includes a road log, descriptions of the geology at each recommended field trip stop, and maps, diagrams and/or photographs to illustrate the concepts and features discussed. (MB)

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GUIDEBOOK FOR FIELD TRIPS IN VIRGINIA

Editor
Joseph D. Exline

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INTRODUCTION

Virginia's geology is very diverse, since its boundaries stretch from the seashore on the east to the folded Appalachians on the west...thus making for interesting geologic diversity. Not many states in the United States and even few of the states comprising the N.A.G.T. Eastern Section can offer this kind of contrast in geology. Therefore, the material presented in this guide was planned, in part, for the purpose of giving field trip participants and users of this guide an opportunity to experience some of this kind of geologic diversity found in Virginia. Diversity is an important factor in creating interest in the subject of geology.

With society's present concern with environmental, energy, and mineral resource consumption problems, the importance of the subject of geology becomes increasingly more apparent to those individuals closely associated with the field. Our educational efforts in geology need to stress the understanding of basic geologic principles; but to have the greatest appeal for those not "as close to the subject", our educational efforts need to put balanced emphasis upon the practical applications of this understanding to the solution of society's problems. The practical application of geologic information in addressing human problems is an aspect of this guide. Relevance should be an important factor in creating greater awareness of the need for the subject of geology.

Providing resources for a more effective educational effort can often come about through the combined efforts of those directly involved with the teaching-learning process. Professional societies, institutions of higher education, state departments of education, and local schools often share mutual concerns. Where human, material, and monetary resources of such agencies are combined, there is usually increased benefit. In the development of this guide, human, material, and monetary resources of several agencies were combined in order to develop a more comprehensive guide to the geology of Virginia and to make copies of the guide available to those individuals directly involved in the teaching of the geology of Virginia. This field guide should be an important resource in encouraging more widespread use of field trips in teaching geology—an important key to a more sound understanding of the subject.

Guide to Field Trips in Virginia, with emphasis upon geologic diversity, application of geologic knowledge, and resource sharing, should prove to be an important aid for those individuals desiring to learn more about the geology of Virginia. Virginia earth science teachers especially should find this guide to be a beneficial resource for planning and conducting field trips for the secondary school earth science students. With this guide to provide the geologic background and relevant geologic site information, teachers can develop appropriate activities which can lead to meaningful field trip experiences for the students. Independently each trip can be developed into a meaningful field experience for students, but collectively the trips can provide for better student understanding of the geology of Virginia.

Joseph D. Exline
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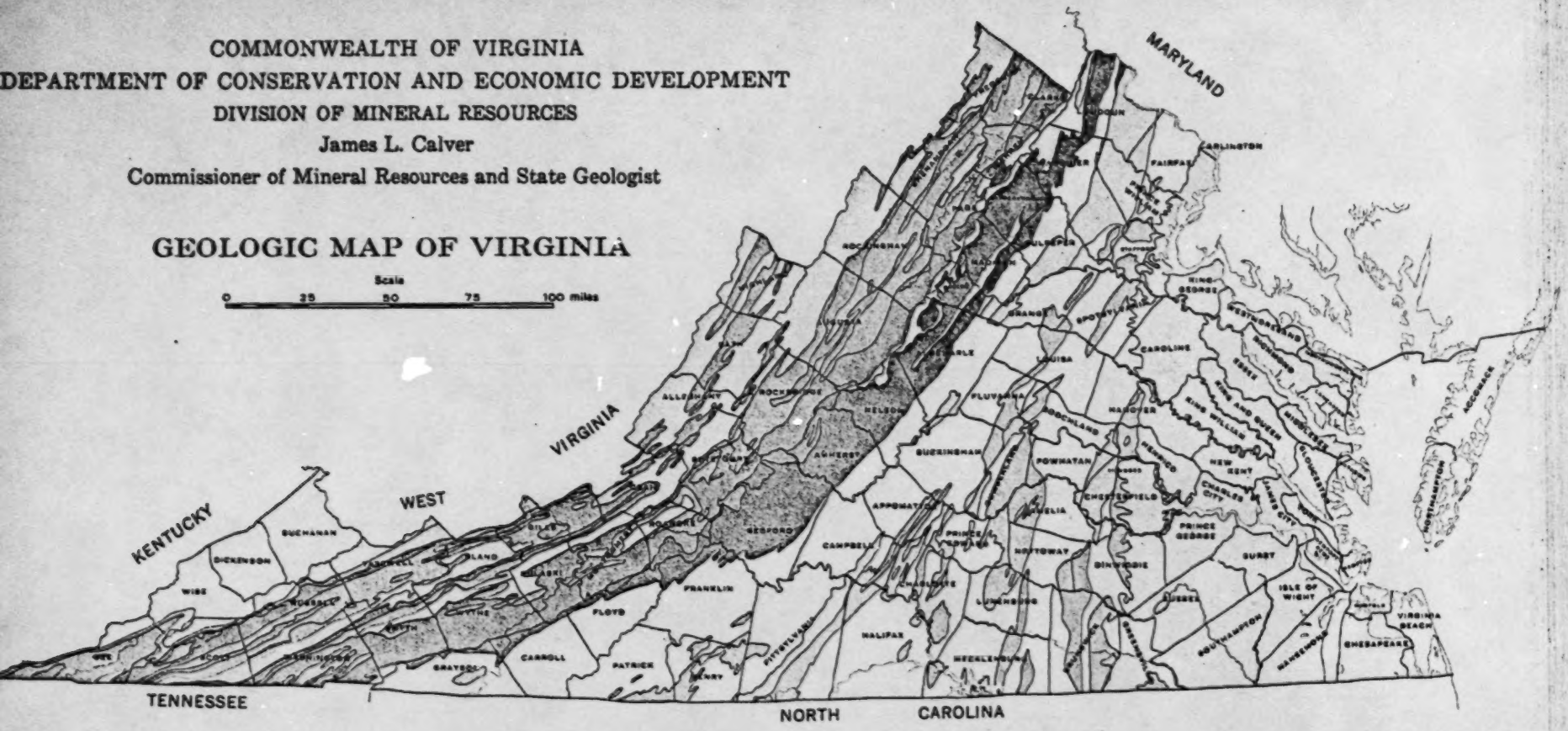
Elementary Administration

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

GEOLOGIC MAP OF VIRGINIA



CENOZOIC

QUATERNARY (1 million years) Sand and gravel. Sand and gravel.

TERTIARY (1-70 million years) Loose or partly indurated sand, clay, marl, and diatomaceous earth. *Sand, clay, marl, and diatomaceous earth.*

MESOZOIC

CRETACEOUS (70-135 million years) Partly indurated sand, clay, and sandstone. *Sand and clay.*

TRIASSIC (180-225 million years) Red and gray shales and sandstones intruded by diabase; some thin coal layers. *Crushed stone, shale, and lightweight aggregate.*

PALEOZOIC

PENNSYLVANIAN (270-320 million years) Sandstone, shale, and coal. *Sand, coal, coke, lightweight aggregate, and natural gas.*

MISSISSIPPIAN-DEVONIAN (310-400 million years) Sandstone, shale, limestone, gypsum, and coal. *Coal, coke, silica sand, gypsum, shale, cement, salt brine, and natural gas.*

SILURIAN-ORDOVICIAN (400-500 million years) Limestone, dolomite, shale, and sandstone. *Lime, crushed stone, cement, shale, and petroleum.*

CAMBRIAN (500-600 million years) Dolomite, limestone, shale, and sandstone. *Crushed stone, sand, zinc, lead, and shale.*

PRECAMBRIAN

VIRGINIA BLUE RIDGE COMPLEX (Older than 600 million years) Granite and gneiss. *Crushed stone*

ROCKS OF UNCERTAIN AGE

GRANITE and GNEISS Granite, granodiorite, augen-gneiss, granite gneiss. *Crushed stone*

METAMORPHIC ROCKS and IGNEOUS INTRUSIVES Schist, slate, phyllite, quartzite, marble, metamorphosed arkose and conglomerate, greenstone, diorite, and gabbro. *Crushed stone, soapstone, anorthosite, slate, dimension stone, kyanite, feldspar, apatite, and titanium minerals*

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ACKNOWLEDGEMENTS

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Joseph D. Exline

*Additional publications on rocks, minerals, fossils, available from:

Division of Mineral Resources
Box 3667
Charlottesville, Virginia 22903

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GEOLOGY OF THE RICHMOND-PETERSBURG AREA

by
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Richmond and Petersburg, Virginia are both situated astride the fall zone separating the igneous and metamorphic rocks and rolling terrain of the Piedmont from the Cretaceous and Cenozoic sediments and flat topography of the Coastal Plain.

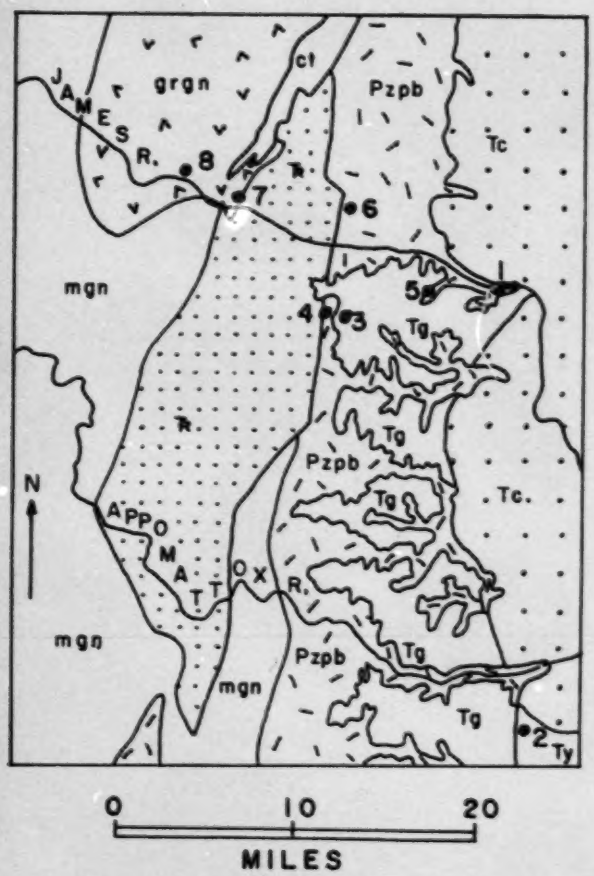

Fig. 1. Generalized geologic map of the Richmond-Petersburg area showing location of stops. Modified from the 1963 Geologic Map of Virginia. grgn = Granite Gneiss; mgn = Mica Gneiss; Psb = Petersburg Granite; ct = Cataclastic Rocks; T = Triassic Sedimentary Rocks; Tc = Calvert Formation; Tg = Tertiary Gravels.

Thus a wide variety of lithologies and geologic ages are represented within a radius of twenty five miles from either city (Fig. 1). A very generalized summary of the rocks of this area has been given by Goodwin (1977), and previous guidebooks to portions of the geology of the Richmond area have been written by Goodwin and Johnson (1970) and Onuschak and Daniels (1974).

West of Richmond are metamorphic rocks composed of gneisses and minor amphibolite. These have been intruded by the Petersburg granite which is exposed in Richmond and Petersburg. This granite contains a wide variety of textures and locally is rich in xenoliths of the country rock. At the turn of the century the Petersburg granite supported an important dimension stone industry and over eighteen quarries were actively worked in the Richmond area. At the present time only crushed stone is produced from the granite. At one locality in Richmond the granite has been dated by Wright, Sinha, and Glover (1975) at 330 $\pm$ 8 million years old. Following emplacement of the Petersburg granite, cataclasis produced a long, narrow belt of cataclastic rocks paralleling and possibly serving as a prior zone of weakness for the faulted western margin of the Richmond basin. This basin contains sedimentary rocks of Triassic age. They consist primarily of shales, arkosic sandstones, conglomerates, and coal. Coal measures in the Triassic basin provided the first coal mined in North America and supported a coal mining industry from the time of the American Revolution up to the middle 1920's. Several smaller Triassic basins occur to the east of the Richmond basin.

Rocks of the Piedmont are usually poorly exposed and can only be observed in quarries, fresh roadcuts, or deep stream valleys. Intense chemical weathering has commonly decomposed the granite deeply to produce a thick saprolite and residual soil. Saprolite tends to be best developed under hills where it may be over sixty feet thick. Fortunately, examination of saprolite often reveals textures and structures which have been preserved from the original rock. Otherwise geologic mapping of this region would be almost impossible. A veneer of gravels of probable Tertiary age cap many of the upland surfaces, particularly at the eastern edge of the Piedmont. These also tend to obscure the bedrock. The Tertiary gravels are extremely thick and well preserved on a broad, flat upland surface

southwest of Richmond. They were deposited, probably by fluvial action, unconformably upon the eroded surface of the Petersburg granite and other Piedmont rocks.

Sediments of the Coastal Plain overlap the basement rocks in the eastern end of Richmond where they thin to a featheredge. They increase in thickness eastward. In former years these sediments provided the clay for many brickyards in the Richmond area. The major Coastal Plain units in this area are the Miocene Calvert Formation and the Pliocene Yorktown Formation. Both may be fossiliferous and the Yorktown Formation is often highly fossiliferous with an extensive and varied invertebrate fauna. Vertebrate fossils also occur within each unit. Coarser grained sediments from the Coastal Plain have long been worked for sand and gravel, and numerous gravel pits occur in this area.

ROAD LOG

Cumulative Mileage	Point to Point Mileage	
		The starting point for this road log will be at the Belvidere toll booth on the Richmond-Petersburg Turnpike, I-95. To reach this point take I-95 south from Fredericksburg.
0.0	0.0	Proceed south on I-95 from the toll booth.
2.0	2.0	Bear right onto Exit 9A onto the Downtown Expressway, Route I-95.
2.9	0.9	Bear right onto Belvidere Street Exit. Pay toll at toll booth, and keep straight to Belvidere St.
3.3	0.4	Turn left onto Belvidere Street. Go south on Belvidere Street.
3.8	0.5	Cross James River on Robert E. Lee Bridge. A good view of the fall zone and Belle Isle in the center of the River can be seen to the west.
4.5	0.7	At south end of bridge turn right onto Riverside Drive. A turn-off to the right allows a good view of Belle Isle, the falls of the James River, and the James River valley.
4.8	0.3	Turn right into James River Park and park at the far end of the parking lot.

STOP 1. PETERSBURG GRANITE AND THE FALL ZONE OF THE JAMES RIVER

Many of the lithologic and structural details of the Petersburg granite can be observed at this locality along the fall zone of the James River in the City of Richmond. Recently that city has developed an extensive park along the south bank and floodplain of the river and numerous trails allow easy access to areas of geological and biological interest.

Rocks referred to as Petersburg granite have been mapped as four separate plutons trending parallel and adjacent to the fall zone from near Fredericksburg, Virginia to the North Carolina border (Calver, 1963). The exposures along the James River occur on a pluton which extends over seventy miles from north of Ashland to south of Dinwiddie and has an exposed width of fourteen miles. In the Richmond area the pluton's western contact with metamorphic rocks is concealed beneath the Triassic sedimentary rocks of the Richmond basin and its eastern border is covered by Coastal Plain sediments. Early studies of the granite were made by Watson (1906, 1910), Darton (1911), Bloomer (1939), and Steidtmann (1945). As summarized by Bloomer (1939), the Petersburg granite consists of three phases: a gray to pink, medium-grained granite; a blue, relatively fine-grained facies; and a porphyritic facies that occurs adjacent to the Richmond basin. The porphyritic facies has more recently been described and delineated by Goodwin (1970) and the granite in the Richmond quadrangle was mapped and described by Daniels and Onuschak (1974). Early reports on the Petersburg granite presented an overly simplistic picture of the lithology as being quite uniform in texture and composition within the three phases described above. In reality the composition ranges from quartz monzonite to granite and the texture varies greatly from fine-to coarse-grained, uniform to highly porphyritic, and nonfoliated to a granite gneiss. Locally the granite contains many xenoliths of the country rock and is cut by felsic, mafic, and pegmatite dikes. Many of these textural variations and structural features can be observed at this locality. The discrepancy between the early descriptions and field observation is due to the fact that most early studies were made in dimension stone quarries. Dimension stone production requires a rock of uniform texture and composition and thus the quarries were established where the rock met those criteria. Thus, descriptions of the granite based on studies of only those quarries were biased by the needs of industry rather than revealing the true characteristics of the granite.

Climb stone steps at northeast corner of parking lot.

At the bottom of the steps and along the south wall are large exposures of Petersburg granite where the rock has been removed along joint surfaces. The first flat vertical face is a fault plane

with some slickensides. Displacement is probably slight and many of the joints within the Petersburg show slight displacement and slickensides. The granite blocks of the steps have been quarried locally and show the rows of holes which were drilled so that wedges could be inserted and driven to break the rock into blocks. Joint planes were also used to advantage by the quarrymen. On the way up the steps the effects of weathering on granite are well displayed and the rock can be seen in all stages of decomposition from firm rock to partially decomposed rock to saprolite grading upward into a soil profile.

At top of hill bear left and cross steel bridge over railroad tracks. Stop at north end of bridge for panoramic view of the James River Valley and massive granite exposures at the fall zone.

From this vantage point the rapids in the bed of the James River and the small floodplain adjacent to the river can be seen upstream. Here the river is split into two channels by Belle Isle which is marked by the heavy vegetation beyond the barren bedrock in the river bottom. The bedrock surface is scarred by well defined joint sets. A large quarry known as the Belle Isle Quarry or the Old Dominion Iron and Nail Works Quarry was opened on the north side of Belle Isle in 1902 and was worked primarily for crushed stone. This quarry has long been abandoned. The main channel of the James River is on the far side of Belle Isle and a dam from the river's south bank to Belle Isle diverts the stream's flow away from the southern channel. As a result, during moderate flow stages of the river large exposures of granite are above water (Fig. 2). During very low flow stages the entire south channel may be dry with only a few rivulets and granite exposures extend uninterrupted from the south bank to Belle Isle. This contrasts strongly with flood stages when turbulent waters have filled the valley of the James River in Richmond to over twenty six feet above its normal surface. Downstream a railroad bridge formerly connecting the east end of Belle Isle to the south bank of the river was partially demolished by the severe floods of 1972 and bears testimony to the violent force of the James River during times of flood.

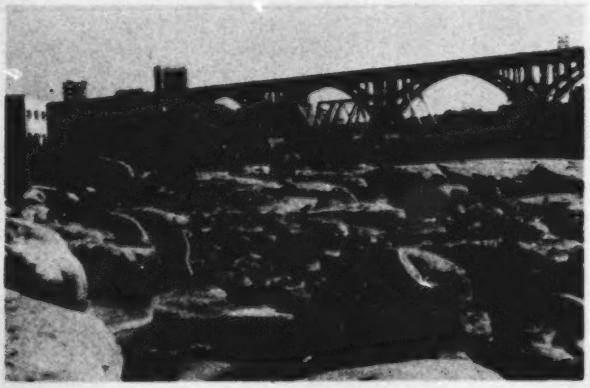

Fig. 2. Vast exposures of Petersburg granite in bed of the James River.

The Fall Zone of the James River is about seven miles wide and is characterized by rapids and waterfalls which mark the head of navigation in the river. This plus an abundance of water power led to the early settlement of Richmond at its present location. The Fall Zone also separates the granitic rocks of the Piedmont upriver to the west from the sediments of the Coastal Plain downriver to the east. The river has easily cut and deepened its path through the sediments while the granite has severly resisted erosion thus creating the zone of falls and rapids.

Descend the winding steps and follow the rough path east to the concrete walkway. Follow this east for about 300 feet until you come to a broad, level granite exposure extending out into the river. Walk onto this exposure.

The granite here is well foliated and contains several dikes which are sub-parallel to the foliation that strikes N25E and dips steeply to the east. Both felsic and mafic dikes cut the granite. A few small faults transect the granite and offset both the foliation and dikes by up to six inches. A small vertical face at the north end of the exposure has a wide variation in texture grading from fine to very coarse in a repetitious sequence. Here the steeply dipping compositional variations can clearly be seen in three dimensions.

The surface of the massive outcrops is scarred by the profuse development of potholes. These circular depressions have been scoured into the solid rock by the abrasive action of coarse sand, pebbles, cobbles, or boulders which are locally swirled around and kept in motion by eddies or the force of the stream's current in a given spot. Once a small pothole develops, the depression tends to accumulate coarse sediments and to be subjected to intensified whirling action of currents. Through this continued localized abrasion they tend to increase in depth and diameter with time. Potholes abound between this point and the dam. A classic photograph by Wentworth taken from near this location looking northwest appears in many elementary geology textbooks and these potholes have recently been described by Goodwin (1978).

The potholes here vary in diameter from a few

to over fifty five inches and some are over sixty inches deep. Many of them are elliptical and appear to have been localized along fractures, as shown by a small elliptical pothole with its long axis along one of the minor faults mentioned above. A majority of the potholes, both elliptical and circular in outline appear to have been localized by some inherent feature of the rock which allowed initial irregularities to develop on the granite's surface, thus causing swirling of the river's currents and the subsequent circular abrasion forming the potholes. Common controls of pothole localization are joints, joint intersections, minor faults, textural and compositional variations within the granite, and strong lithologic contrasts at the borders of dikes, veins and xenoliths. Joints, occurring either as open or closed fractures, have been dominant sites of pothole development. The growth of potholes appears to have been a major process in erosion of the bedrock channel here and all stages can be observed from isolated potholes on flat surfaces to large elliptical potholes aligned along joints to small channels which show large pothole remnants as curved surfaces on their near vertical sides (Fig. 3).

Fig. 3. Several potholes occurring along the side of a small channel cut into the granite.

Jointing is well developed in the Petersburg granite and two steeply dipping joint sets are dominant here with strikes centered around N60E and N15W. These joints along with the sheeting were used to advantage by quarrymen. Some small scale former quarrying operations can be seen in the bed of the river just south of this point. It is interesting to note that in the area of these small quarrying endeavors the granite lacks a strong foliation and is uniform in texture.

The most obvious dike occurs adjacent to the concrete walkway at the eastern end of the broad, flat exposure. Here a closely fractured aplite dike from twelve to eighteen inches wide stands slightly above the level of the granite. Its finer texture and quartz-rich composition have resisted weathering and stream erosion more effectively than the host granite. This dike can be traced to the south of the concrete walkway and during low water stages can be followed completely across the channel to the corner of the large concrete building on Belle Isle. In this distance it maintains a surprising uniformity of thickness.

Walk eastward along the concrete walkway to twenty feet west of the railroad bridge and south of the walkway.

Along this walk numerous fresh specimens of granite and gneissic granite as well as good mineral specimens of feldspar, quartz, and biotite can be observed and collected if desired. Also, close examination of the rounded cobbles which have been transported and deposited by the James River will reveal lithologies from many geologic units across the Piedmont and Blue Ridge.

A broad, flat exposure of granite west of the railroad bridge and a small raised exposure to the west of that show complexities of gneissic banding and xenoliths within the Petersburg granite. The raised exposure has excellent foliation defined by compositional and textural variations. Some foliation planes are truncated by others and several small xenoliths or mafic segregations occur. The broad, flat exposure adjacent to and under the railroad bridge contains numerous spectacular xenoliths, some of which measure over four feet across. These are fragments of the enclosing host gneisses which were broken off during intrusion of the granite and have been preserved within it. Foliation within several adjacent xenoliths at the west end of this exposure has diverse orientations and is at a strong angle to the granite's well developed gneissic banding which diverges and wraps around the xenoliths. The xenoliths have sharp contacts with the host rock and one xenolith contains a small fold. These xenoliths and others beneath the railroad bridge occur in zones which extend parallel to the foliation and can be traced northward to Belle Isle. A narrow mafic dike cuts across the granite and one of the xenoliths. Several other xenoliths occur under the railroad bridge and in one group individual fragments are separated by only a few inches of granite. If the intervening granite were mentally removed, it appears as if these xenoliths would nestle together to form one large original block.

This area of strong gneissic banding and heavy contamination by xenoliths appears to be best

developed at the pluton's eastern exposed edge. A quarter of a mile to the east xenoliths and contorted foliation abound while westward the granite becomes less foliated and xenoliths are scarce to absent. This suggests that these exposures may be near the eastern margin of the pluton or were near the roof of the pluton at the time it was emplaced.

ROAD LOG CONT'D

Cumulative Mileage	Point to Point Mileage	
		Leave parking area at James River Park. Turn left on Riverside Drive.
5.1	0.3	Turn right on Cowardin Avenue.
5.6	0.5	Turn left on Hull Street, Route 360.
6.4	0.8	Turn right on 4th Street.
7.1	0.7	Proceed on 4th Street to Richmond-Petersburg Turnpike (toll road; I-95). Go south on I-95 toward Petersburg.
27.6	20.5	Bear right at interchange 3 and take Washington Street exit. Proceed west on Washington Street.
28.2	0.6	Turn left on Market Street.
28.4	0.2	Turn right on Halifax Street
29.7	1.3	At entrance to A. P. Hill Elementary School, turn left off Halifax and park in lot in front of the school on Talley Avenue. Walk to back of school and go through hole in fence to Lieutenant Run.

STOP 2. LIEUTENANT RUN

NOTE: This section, The Geology of the Lieutenant Run Exposure, Petersburg, Virginia, was written by Blake W. Blackwelder and Lauck W. Ward of the U. S. Geological Survey, Reston, Virginia.

Lieutenant Run is a small stream in Petersburg, Virginia that has cut through rock units of the Chesapeake Group (Fig. 4), a sequence of strata deposited in extensive Miocene and Pliocene (20 million to about 2 million years ago) embayments in the Maryland and Virginia Coastal Plain. The fossiliferous rocks exposed here have been visited or studied by Bailey (1843, 1844), Lea (1840, 1843), Tuomey (1843), Woodward (1887), Gardner (1943, 1948), and Ward and Blackwelder (in press).

During deposition of the Chesapeake Group, seas reached as far inland as Washington, D. C., Richmond, Va., and Petersburg, Va. In these large embayments, normal to nearly normal marine salinities prevailed, and many species and genera of mollusks flourished. The mollusk assemblages are representative of a marine-warm-temperature climatic province not presently existing off the Atlantic Coast of the United States. At present, a sharp thermal boundary is found at Cape Hatteras where the mild-temperate waters off Virginia and the subtropical waters off North Carolina meet. The warm-temperate waters present in the Virginia region during late Miocene and Pliocene time enabled many mollusk genera, now limited to separate climatic zones, to coexist. These animals adapted to the warm-temperate waters of these large embayments in the coast line. When the basins of the Chesapeake Group were closed because of a regression of the seas, and the sharp thermal convergence at Hatteras developed, a very large proportion of the mollusks became extinct.

In these shallow embayments, many filter-feeding bottom dwellers flourished. Among the more abundant forms were *Chesapecten* (a scallop) and *Mercenaria* (the hard-shell clam). Early in Chesapeake Group time when the basins had just opened, species of both these forms were relatively thin shelled. *Chesapecten*, at least in its juvenile growth stages, could swim to avoid predation by snails which use radulas to bore holes into mollusk shells. By the time that the beds of Pliocene age at Lieutenant Run were deposited, very efficient gastropod predators appeared in the basin, and other predators, such as starfish, also were present.

In apparent response to this increasingly heavy predation, the morphology of *Mercenaria* tended toward extremely heavy, thickened forms having a folded commisure between the valves so that starfish could not twist one valve past another and the snails could not drill through the thick shell. Similarly, *Chesapecten* developed a very heavy thickened shell; it also developed very pronounced ribs which also would have provided protection. Both *Chesapecten* and *Mercenaria* developed tightly closed shells that do not gape. Also present at Lieutenant Run are several very thin shelled scallops; however these were no doubt efficient swimmers and thus could avoid predation.

At the central part of the Lieutenant Run exposure, two different rock units are exposed. The lower one, a fine shelly sand termed the Eastover Formation, was deposited in late Miocene time between about 6.5 million and 9.0 million years ago. These ages are based in part on radiometric dating methods using decay ratios of potassium to argon in glauconite, a green mineral that forms as sand-sized grains on the sea floor. After the Eastover Formation was deposited, the sea regressed; apparently, almost 2 million years elapsed

before deposition resumed. The Mediterranean Sea became enclosed at this time because of movements in the earth's crust. The Mediterranean virtually evaporated and thick gypsum sequences formed. The contact between the Eastover and the overlying unit seems to represent this important event in earth history. A new transgression in the Pliocene deposited the very shelly sands of the Yorktown Formation over an eroded and burrowed surface of the Eastover Formation. Quartz pebbles along the contact between the Yorktown and the Eastover are evidence that deposition was interrupted. Also, shells and sediments from the Yorktown beds fill burrows into the Eastover. By radiometric methods, the Yorktown has been dated at about 3.5 million to 5.0 million years old. Fossils in the Eastover, especially the *Chesapecten* species, are different from those in the Yorktown. The species of *Chesapecten* are good stratigraphic indicators because of relatively rapid rates of evolution. The Eastover species *Chesapecten middlesexensis* became extinct by Yorktown time when *Chesapecten madisonius* first appears.

Some of the common species in the Yorktown here are *Chesapecten madisonius* (Say, 1824), *Mercenaria tridacnoides* (Lamarck, 1818), *Mulinia congesta* (Conrad, 1833), and *Ostrea sculpturata* (Conrad, 1840). Plates 1 and 2 illustrate some of the common fossils found in the upper member of the Eastover Formation and in the Yorktown Formation. Borings of carnivorous gastropods are apparent on some of the bivalves in these figures.

Figure 4 is a composite section at Lieutenant Run. The most easily accessible part of this section exposes the upper part of the Eastover Formation and the lower and middle part of the Yorktown Formation. The Yorktown here is much more shelly and sandy than the Eastover, and the sand in the Yorktown is coarser grained. Also present in the Yorktown are abundant microfossils, including ostracodes and foraminifers, which can be studied under a binocular microscope.

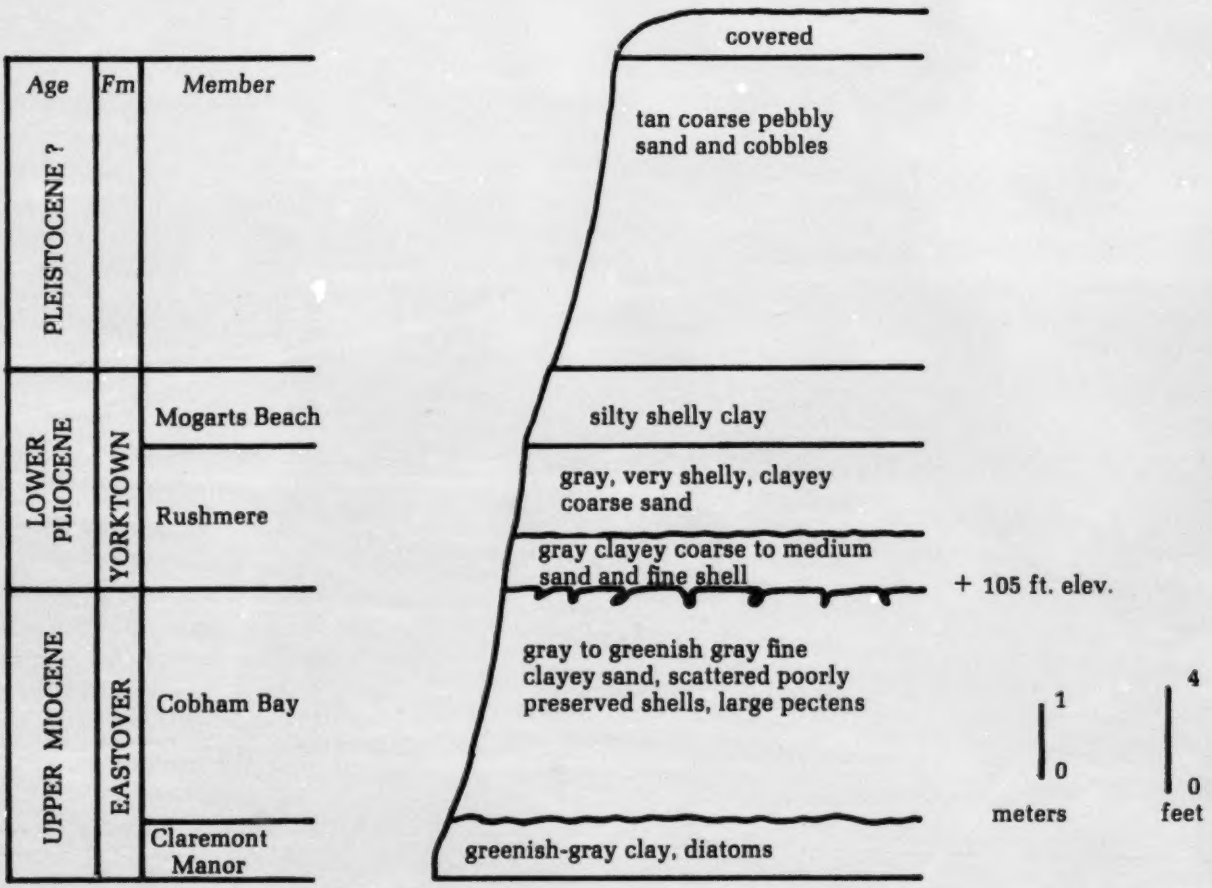

Fig. 4. Composite section from Lieutenant Run, Petersburg, Va.

PLATE 1—COMMON MOLLUSKS IN THE YORKTOWN FORMATION

Fig.

1. *Chesapecten septenarius* (Say, 1824). Right valve, length 68.8 mm, height 66.3 mm.
2. *Chesapecten madisonius* (Say, 1824). Right valve, length 90.5 mm, height 85.8 mm.
3. *Fusinus exilus* (Conrad, 1832). Apertural view, height 50.3 mm.
4. *Busycon maximum* (Conrad, 1838). Apertural view, height 260.0 mm.
5. *Ostrea raveneliana* Tuomey and Holmes, 1855. Left valve, length 102.5 mm, height 114.3 mm.
6. *Ostrea sculpturata* Conrad, 1840. Left valve, length 42.1 mm, height 57.2 mm.
7. *Astarte undulata* Say, 1824. Right valve, length 28.4 mm, height 26.4 mm.
8. *Glycymeris tuomeyi* (Dall, 1898). Right valve, length 35.5 mm, height 31.8 mm.
9. *Glycymeris americana* (DeFrance, 1826). Right valve, length 60.7 mm, height 55.6 mm.
10. *Mercenaria rileyi* (Conrad, 1838). Right valve, length 94.0 mm, height 70.2 mm.
11, 12. *Pseudochama corticosa* (Conrad, 1833). Exterior and interior views of the right valve, length 46.1 mm, height 51.5 mm.
13. *Astarte concentrica* Conrad, 1834. Right valve, length 22.6 mm, height 20.5 mm.
14. *Mulinia congesta* (Conrad, 1833). Right valve, length 17.4 mm, height 12.9 mm.
15. *Mercenaria tridacnoides* (Lamarck, 1818). Right valve, length 106.1 mm, height 83.8 mm.
16. *Planicardium virginianum* (Conrad, 1839). Left valve, length 95.9 mm, height 120.0 mm.

PLATE 2
COMMON MOLLUSKS IN THE COBHAM BAY MEMBER OF THE EASTOVER FORMATION

Fig.

1. *Placopecten princepoides* (Emmons, 1858). Right valve, length 155.8 mm, height 140.0 mm.
2, 3. *Scapharca carolinensis* (Dall, 1897). Right and left valves of same specimen. Right valve, length 44.9 mm, height 44.9 mm, height 46.7 mm. Left valve, length 44.7 mm, height 46.8 mm.
4. *Glycymeris* sp. Length 29.2 mm, height 27.9 mm.
5. *"Pecten" urbannaensis* (Mansfield, 1928). Right valve, length 77.3 mm, height 73.5 mm.
6. *Chesapecten middlesexensis* (Mansfield, 1936). Right valve, length 115.2 mm, height 110.9 mm.

ROAD LOG CONT'D

Cumulative Mileage	Point to Point Mileage	
		Turn around and go back to Halifax Street. Turn right onto Halifax Street and proceed north.
31.1	1.4	Turn right onto Wythe Street.
31.6	0.5	Bear left to entrance to I-95 north. Go north on I-95 toward Richmond.
46.2	14.6	Bear right and take Exit 7, to Chippenham Parkway, Route 150. Proceed west on Chippenham Parkway.
47.6	1.4	Road climbs up scarp.
50.8	3.2	Petersburg granite is exposed in the stream and in road cuts.
54.0	3.2	Bear right onto the Midlothian Turnpike, Route 60 exit.
54.2	0.2	Turn left onto Midlothian Turnpike. Proceed west on the Midlothian Turnpike. This exit is at the top of a scarp separating regressive sediments of the Coastal Plain to the east from high level gravels to the west. The regressive sediments occur up to an elevation of 240 feet while the base of the high level gravel is at 250 feet above sea level. Granite saprolite is exposed on the face of the scarp between these two elevations. For the next five miles Route 60 traverses a broad, relatively undissected and flat upland surface underlain by high level gravels. The gravels can be seen in several roadcuts, construction sites, and gravel pits.
59.6	5.4	Pull off on right shoulder of road by steep roadcuts as you go down a long hill. Gravels are exposed in this cut.

STOP 3. HIGH LEVEL GRAVEL

A cut about 30 feet deep on the north side of U. S. Highway 60 exposes coarse, upland gravels which unconformably overlie a saprolite of the Petersburg granite. Unfortunately this exposure is now weathered and overgrown, but the gravels are well exposed in a large gravel pit immediately behind the road cut.

These gravels are part of an extensive upland gravel on the eastern Piedmont of Virginia between the James River and the Appomattox River. It is

well exposed in the vicinity of Bon Air and Midlothian and occupies a broad, flat, relatively undissected upland surface in this area. The gravels range in thickness from a featheredge to more than 40 feet and unconformably overlie the Petersburg granite and other crystalline rocks of the Piedmont as well as Triassic sedimentary rocks of the Richmond basin. The older Piedmont rocks were probably weathered to a saprolite before the gravels were deposited on a relatively flat surface, locally cut by channels, having a gentle eastward inclination of about nine feet per mile. The basal contact of the gravel is usually sharp and is often marked by a thin basal conglomerate. Here the contact is at an average elevation of 340 feet and it has been traced to an elevation of 450 feet west of the Midlothian quadrangle. To the east the contact descends to a minimum elevation of around 250 feet near the eastern border of the Bon Air quadrangle. Where exposed on the sides of hills, the contact is commonly expressed by a pronounced break in slope and the gravel has acted as a resistant capping.

The high-level, upland gravels in this area were briefly described by Rogers (1884) and were noted by Shaler and Woodworth (1899). Darton (1911) described the high level gravels in the Richmond area referring to them as the Lafayette formation of Pliocene (?) age. Since then several geologists have attempted to assign ages ranging from Miocene to Pleistocene to these gravels. Unfortunately since they are isolated and have been truncated by erosion on all sides they cannot be correlated directly with other known upland gravels.

In this cut the contact between the granite and the gravels dips eastward at 10 to 15 degrees. Immediately above the contact discoidal cobbles are oriented parallel to the contact but higher in the gravel sequence the cobbles have their long axes nearly horizontal, suggesting that they have filled a former channel which had been cut into the granite. The Petersburg granite crops out near the base of the exposure's western end. The granite has been deeply weathered and completely converted to saprolite in which the feldspars have been thoroughly altered to clay. The original texture of the rock can be seen but only a few solid grains of quartz remains. A mafic dike several feet wide cutting the granite has also been completely converted to saprolite producing a deep red clay.

The gravel-granite contact is sharp to gradational due to slight mixing and is overlain by a thin cobble varying from three inches to a foot in thickness. Above the cobble zone is a pronounced four foot thick silty clay zone. The clay appears massive on fresh exposures but shows thin laminae when weathered. Overlying the clay is 25 feet of coarse gravel with a medium to coarse sand matrix. In general the clasts are well-rounded but have a sphericity ranging from low to high. There is slight parallelism of discoidal clasts. Most of the clasts are of massive quartz, vein quartz, quartzite, or quartz sandstone. Many of the quartzite and sandstone clasts are highly decomposed and friable. The clasts attain a maximum dimension of 8 inches and are thick bedded. The gravels are weakly cemented and become increasingly iron-stained and reddish in color upward. A few deep reddish-brown, clay filled fractures cut across the bedding of the gravels.

Behind this roadcut and not visible from the road is a large gravel pit which has extensive exposures of gravel in its walls. This pit will not be worked much longer because it has been extended laterally nearly as far as possible and its depth is limited by the granite-gravel contact. Maximum depth has been attained in many places and granite saprolite can be seen locally in the floor of the pit. This pit, and other large pits in the upland gravels, has not been worked for its sand or gravel content because the gravel is of poor quality containing deeply weathered, soft clasts, much iron oxide, and a matrix which is difficult to separate from the clasts. Rather, it is used primarily for fill material.

On the south wall the composition and size variation of the clasts are clearly shown. Deeply decomposed clasts are abundant and many of the quartzite and sandstone cobbles have a soft and easily broken sugary texture. A complete graduation from fresher gravel at the base of the exposures to deeply weathered gravel upward is prominent. In places the gravel is thoroughly decomposed producing an unusual, intensely mottled deep red and gray clayey gravel saprolite with a few, rounded quartz pebbles or cobbles remaining. It grades upward into a strongly hematitic deep red zone with some pebbles and cobbles in a clay matrix and even in the topsoil a few rounded quartz clasts remain. A few widely-spaced pronounced deep reddish-brown, clay filled fractures up to six inches wide cut diagonally across the face of the exposure. The bedding within the gravel can best be seen on the pit's north wall beneath the housing development. There the beds, usually several feet thick, are nearly horizontal or gently dipping to the east.

ROAD LOG CONT'D

Cumulative Mileage	Point to Point Mileage	
		Continue west on Route 60.
60.1	0.5	Pull off on right shoulder of highway by pipeline just before reaching the stream at the bottom of the valley.

STOP 4. TRAISSIC-GRANITE CONTACT

On the north side of U. S. Highway 60 are small exposures in the road cut. Although small, they reveal the contact between the Petersburg granite and Triassic sedimentary rocks.

Proceeding from the gas pipeline eastward, the first exposures are of weathered, brown, micaceous, arkosic sandstone. This is typical of Triassic arkosic sandstones in the Richmond area. At the eastern end of the exposures is fairly fresh, porphyritic Petersburg granite. By digging into the bank between the two exposed lithologies, it is possible to determine the position of the contact quite closely. In former years the exact contact could be exhumed. No evidence of faulting was seen and the Triassic sediments appear to lie unconformably upon the granite. This is the only location where the actual granite-Triassic contact of this particular basin can be observed or approximated with confidence.

The contact seen here is not the edge of the Richmond basin but rather is on the boundary of a much smaller basin, less than 1000 feet wide, which lies to the east of the Richmond basin and is separated from it along Rt. 60 by a quarter of a mile of intervening Petersburg granite. Coal was produced from this small basin and mines existed both north and south of Route 60. A short distance north along the pipeline are numerous prospect pits and waste heaps from old mining activity. They yield specimens of sandstone, shale, and coal as well as carbonized fragments of plant fossils. Some fossil fishes have also been obtained from these rocks.

Although coal is no longer mined from the Richmond basin, its exploitation was an important and interesting part of Virginia's mineral heritage. Coal from this area was first reported in 1701, but it was not until 1780 that mining was carried out on a continuing basis. Coal is exposed on both the eastern and western margins of the Richmond basin and presumably is continuous beneath the basin over much of its extent. Active mining centers developed near the towns of Gayton and Manakin north of the James River and Midlothian and Winterpock south of the James River. Although the coal is a good quality bituminous coal, the mining industry had intermittent production with active mining terminating around 1930. At the present time no coal mines are in production in the Richmond area. However, many old pits and uncapped shafts still exist in the woods around this area and present a hazard to the unwary explorer. Accounts of the coal, the Richmond basin, and its mining history are given by Ashburner (1888), Shaler and Woodworth (1899), Woodworth (1902), Roberts (1928), and Goodwin (1970).

ROAD LOG CONT'D

Cumulative Mileage	Point to Point Mileage	
		Turn around and proceed east on Route 60.
61.1	1.0	Turn left on Huguenot Road. Proceed north on Huguenot Road.
64.0	2.9	Turn right on Shoreham Drive.
64.6	0.6	Park in cul de sac at end of Shoreham Drive. Walk to railroad tracks next to end of Shoreham Drive and walk east (left) along the railroad tracks for approximately .4 mile.

STOP 5. GRAVEL-GRANITE CONTACT

At this locality a large exposure of the contact between Petersburg granite and high level Tertiary gravels can be observed. The nonconformity between the two lithologies is at an elevation of approximately 300 feet and represents a missing time interval of over 300 million years.

The granite, which has been reduced by weathering to saprolite, is a highly porphyritic phase of the Petersburg granite which extends from this locality westward to beneath the Triassic basin. It is dominated by large potassium feldspar phenocrysts, some of which are two inches long. These have a crude parallelism delineating faint foliation in the granite. One set of cleavage planes in the feldspar is parallel to this foliation. The matrix weathers dark gray and is medium-grained.

The granite-gravel contact is somewhat elusive as some reworking of the granite has occurred while the lowermost gravels were being deposited. A one inch thick pebble zone marks the base of the gravels and is overlain by 1.5 feet of well-rounded quartz clasts disseminated in a yellow-orange matrix of angular, fine to very fine quartz and feldspar sand with 10 to 15 percent clay. Overlying this is a bed of grayish-yellow, fine to coarse, rounded silty quartz sand with minor angular feldspar grains and a few rounded granules. It is overlain by a five foot thick sequence of grayish-yellow, silty, finely laminated clay. Above the clay are five feet of gravel extending to the top of the exposure. The laminated clay-gravel contact is undulatory and is immediately overlain by a half inch thick ferricrete layer. The gravels contain abundant clasts from one-half to five inches in diameter which are composed dominantly of sandstone, quartz, and quartizite. Some clasts are discoidal and a few are of siltstone, metamorphic rocks, and igneous rocks. The matrix is a fine to

coarse, sub-angular to well-rounded quartz sand with abundant coarser angular feldspar grains and a few percent of clay. Fining upward sequences occur within the gravels.

ROAD LOG CONT'D

Cumulative Mileage	Point to Point Mileage	
		Turn around and go west on Shoreham Drive.
65.2	0.6	Turn right on Huguenot Road. Proceed north. To the west, directly across from the intersection of Shoreham Drive and Huguenot Road is a housing development which is built in a broad, shallow basin. Over 21 similar shallow, elliptical depressions occur on the upland surface underlain by the high level gravels. These basins are floored by gravel, have low rims of fine sand containing a few pebbles, and their interiors are filled by five to ten feet of massive brownish-gray silty clay with a few scattered, rounded quartz pebbles. Drainage is toward the centers of the basins and the clayey sediments are usually moist and support a water-loving flora. The basins vary in maximum diameter from .12 mile to over 1 mile and the long axes are roughly alligned at about N70W. They are similar in many respects to the "Carolina Bays" which are common on the Coastal Plain. Huguenot Road is on one rim of this basin and the opposite rim can be seen at the far side of the subdivision. Numerous drainage ditches traverse the subdivision in order to remove the water which normally drains inward toward the center of the basin.
66.9	1.7	The contact between high level gravels and Petersburg granite occurs near this point. Small exposures in roadcuts to the right show gravel and the next exposure down the road to the left contain granite saprolite.
66.4	1.3	Cross the James River. This point is near the western edge of the fall zone and rapids and granite exposures can be seen in the bed of the river to the east. A well developed floodplain of the James River can be seen from the north end of the bridge. Although this may be an inviting place to build, the house and outbuildings to the right have been inundated by flood waters several times. Note that the outbuildings are now built on pilings in an attempt to keep them above water when the river overflows its banks.
69.3	0.9	Turn left onto River Road. Proceed west on River Road.
71.6	2.3	Turn right on Parham Road. Gravels are exposed in cuts at this intersection.
73.3	1.7	Turn left onto Patterson Avenue, Route 6 and proceed west on Patterson Avenue.
74.6	1.3	Granite saprolite is exposed in the cuts on either side of the road.
76.1	1.5	Turn off to the right into the Tuckahoe Village Shopping Center and park by the Laundry at the northeast end of the shopping center.

STOP 6. SPHEROIDAL WEATHERING IN PETERSBURG GRANITE

Although the Petersburg granite is usually deeply weathered and reduced to a saprolite as in the deep road cuts along Route 6 to the east of this point, here large rounded exposures of fresh granite exhibiting pronounced spheroidal weathering occur. These exposures were formerly much more extensive and large blocks of fresh rock blasted off during construction of the parking areas line the parking lot to the west. The granite is medium-grained and slightly porphyritic with large K-feldspar phenocrysts. Widely spaced but well developed joints have served as sites of deep weathering while between joints the rock has remained relatively unweathered. In this way the massive granite surface has been weathered into a series of rounded masses. In some cases spherical, large boulders of granite have become detached from the main mass.

This exposure is within 200 feet of the border of the Richmond Triassic Basin to the west and dur-

ing construction for the shopping center the contact between the Petersburg granite and Triassic sedimentary rocks was exposed. The Triassic arkosic sandstones, shales, and thin conglomerates dip gently to the west and no evidence of faulting could be seen at the contact.

Similar exposures of relatively unweathered granite occur near the contact with the Triassic basin further north and were noted by Shaler and Woodworth (1899, p. 507, plate XLIX) in their classic report on the Richmond basin. They postulated that these were produced by partial weathering of the granite prior to deposition of Triassic sediments which subsequently covered the granite and protected it from further decomposition until it was more recently exhumed as weathering and erosion removed the Triassic cover. An alternate explanation for the presence of this unweathered granite is that it invariably occurs adjacent to the Triassic basin which is a topographic lowland as well as a structural basin. Thus more rapid erosion along the basin margins has stripped off the saprolite exposing the unweathered granite.

ROAD LOG CONT'D

Cumulative Mileage	Point to Point Mileage	
		Continue west on Patterson Avenue.
77.0	0.9	To the right is Carbon Hill which was actively mined for coal prior to 1900. Small roadside exposures of Triassic shale and arkosic sandstone occur on the south side of the road just over the crest of the hill. A major mining center was in the former town of Gayton, across Tuckahoe Creek to the northeast of Carbon Hill.
80.4	3.4	The town of Manakin was another center of mining activity. These coal seams occur near the western border of the Richmond basin and the contact with granite occurs just west of Manakin.
80.9	0.5	Turn left into the entrance of the Boscobel Granite Company quarry and proceed downhill to the quarry office. Check in with the quarry superintendent and sign release. Hard hats are required at this locality. Continue downhill and bear right. Park on the right away from any quarrying or truck activity before the steep road into the main pit. Do not go into the main pit.

STOP 7. BOSCOBEL QUARRY

This large quarry has been in operation since 1924 and reports suggest that rock has been quarried from this location for over 100 years. It is situated on the outer edge of the floodplain of the James River and the river is beyond the trees on the far side of the railroad tracks. Although the quarry is well sited for rail transportation, its location on the floodplain presents obvious problems. During the severe floods of 1972 this quarry became the largest swimming pool in the Richmond area. At the present time some of the overburden and waste rock is being used to build dikes between the quarry and the river.

At the eastern edge of the quarry a large normal fault separates Triassic sedimentary rocks of the Richmond basin to the east from granite to the west. The fault strikes approximately N-S and dips about 60° E. It was formerly well exposed in a wall near the quarry entrance and was marked by a two foot wide zone of breccia and mylonite. The Triassic sedimentary rocks adjacent to the fault were highly folded and cut by numerous faults of small displacement. Most of these were also normal faults and their frequency diminished away from the major fault.

Steidtman (1945) described three lithologies dominating the granite in the quarry. One is a fine-grained, greenish rock composed of quartz, plagioclase feldspar, and minor amounts of biotite and potassium feldspar. The second is a medium- to coarse-grained pegmatitic pink granite containing quartz, potassium feldspar, plagioclase, and muscovite. The third rock type is a mixture of the other two. These lithologies occur as nearly horizontal layers and the compositional changes can be clearly seen on the quarry walls.

The Triassic rocks are composed of arkosic, micaceous, carbonaceous sandstone which is black to dark gray when fresh but weathers orange-brown; micaceous, carbonaceous, black shale which frequently weathers reddish-brown; and thin coal seams. The sandstones are cut by small faults and are highly jointed. Well developed slickensides occur on some of the coal seams and shale beds. This is the best exposure of Triassic rocks in the Richmond basin. Pieces of stems and other plant fossils occur within the rocks and numerous fossil fish have been obtained from this locality. Fish scales are locally abundant.

At the top of the quarry is an outstanding example of the deep weathering of the eastern Vir-

ginia Piedmont. There, an exposure contains over forty feet of granite saprolite becoming increasingly decomposed upward and grading into a normal soil profile. Downward beneath the exposure the saprolite grades into undecomposed granite.

ROAD LOG CONT'D

Cumulative Mileage	Point to Point Mileage	
		Retrace route back to Route 6. Turn left on Route 6 and proceed west.
84.1	3.2	Pull off on right shoulder of road by large exposures in the road cut just beyond a sharp curve in the road.

STOP 8. STATE FARM GNEISS

This exposure at the edge of a broad, well developed floodplain of the James River, is of highly contorted State Farm gneiss which has a conspicuous foliation defined by the biotite. The gneiss has been injected by granite and locally is migmatitic. At the west end of the exposure numerous highly contorted veins and ptygmatic folds occur. Euhedral to subhedral crystals of magnetite are abundant in the rock in the center of the exposure. The presence of this mineral has led to the rapid development of a pronounced reddish stain on the weathered surface of the rock. To the east of the exposure's center a vertical, five foot wide pegmatite dike is prominent. This simple pegmatite contains crystals over five inches long as is composed primarily of quartz, potassium feldspar, plagioclase, and biotite. The gneiss adjacent to the pegmatite is highly deformed and shows contorted compositional variations. A small fold in the gneiss occurs to the east of the pegmatite. The rock at this locality is more highly deformed than most of the gneisses exposed in this area. However, it illustrates some of the complexities which exist in the metamorphic rocks of the eastern Piedmont.

ROAD LOG CONT'D

End of trip. Turn around and take Route 6 back to Parham Road. Turn left on Parham Road and follow it north to the intersection with I-64. This will take you east to I-95 or west to Charlottesville.

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GEOLOGY, SOILS AND LAND USE IN CENTRAL VIRGINIA

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The study of soils has been one of the neglected areas of geology. However, this neglect is rapidly giving way in the face of constantly increasing demands on our soil resources. Soils are essential: (1) for the growth of food, fiber, and other crops, (2) as the source of soil-derived industrial raw materials, such as clays and residual ores, and construction materials, and (3) as foundations for the construction of man-made structures. Further, the study of soils has become an integral part of other geologic investigations in such areas as geomorphology and glacial geology.

Central Virginia provides an excellent setting in which to study soils in the context of their geologic origin and historical and contemporary land use. The bedrock geology of this area is comprised of a complex of metamorphic and igneous rocks of the Piedmont, and sedimentary and igneous rocks of the Culpeper Triassic Basin (Figure 1).

The most common Piedmont rocks in central Virginia are metabasalt (Catoctin Formation) and metasedimentary slates, phyllites, schists and gneisses. Intruded into these rocks are granites, gabbros, and other igneous rocks. The Culpeper Basin is the largest of several Triassic basins occurring in Virginia. The basin has been mapped as a graben structure bounded by northeast-southwest trending normal faults. As the basin subsided clastic sediments from the contiguous highlands were carried into the lowland and deposited as a series of red beds, principally siltstones and shales. Subsequently diabase was intruded into the sediments in the form of sills, dikes and stocks.

The soils of Central Virginia reflect the complex underlying geology. This relationship can be best observed in the residual soils which have formed directly from the underlying bedrock (Figure 2). These soils exhibit a strikingly wide range of characteristics. The most common soils of the Piedmont are the acidic, micaceous silt loams, overlying schists and phyllites. At the other extreme are heavy clay soils which form over basic rocks such as gabbro and diabase. Between these two extremes are a number of interesting soils, such as the red kaolinite-rich residium weathered from the Catoctin Formation and the soils formed from the Triassic sediments.

One of the principal objectives of the field trip is to observe the land use patterns which have developed in response to different soil characteristics. Because of the highly variable soils and geology and a relatively long human history this area lends itself particularly well to an historical view of man's use of the land (Figure 3).

ROAD LOG

Cumulative Mileage	Point to Point Mileage	
0.0	0.0	Leave Sheraton Inn Fredericksburg, Va. and proceed west on Rt. 3
11.9	11.9	Turn left onto Rt. 613 (Brockroad)
12.3	0.4	**STOP 1 WILDERNESS BATTLEFIELD**

Brockroad Soil—This soil series has an interesting history. The parent material from which the soil formed, was deposited by streams (fluvial), hence the Brockroad is called a transported soil. Today, streams in this area have eroded to a much lower level, leaving the ancient stream bed deposits as cappings on the upland surfaces. The soil is very stony and acid. It is also poorly drained as shown by the bleached subsoil in the pit.

Land Use Implications—Much of this area was cleared and farmed during Colonial times; however, because of the low productivity of the soil most of it has now reverted to forest. Another major activity in this area was the cutting of the hardwood timber for the production of charcoal. Governor Alexander Spottswood constructed iron furnaces at Germanna Ford near here in the early eighteenth century and used charcoal from this area. One theory holds that this area became known as The Wilderness because of the tangle of second growth forest left by the extensive charcoal operations. Probably a better reason for the extensive forests here is the nature of the soils which were poor for agricultural use.

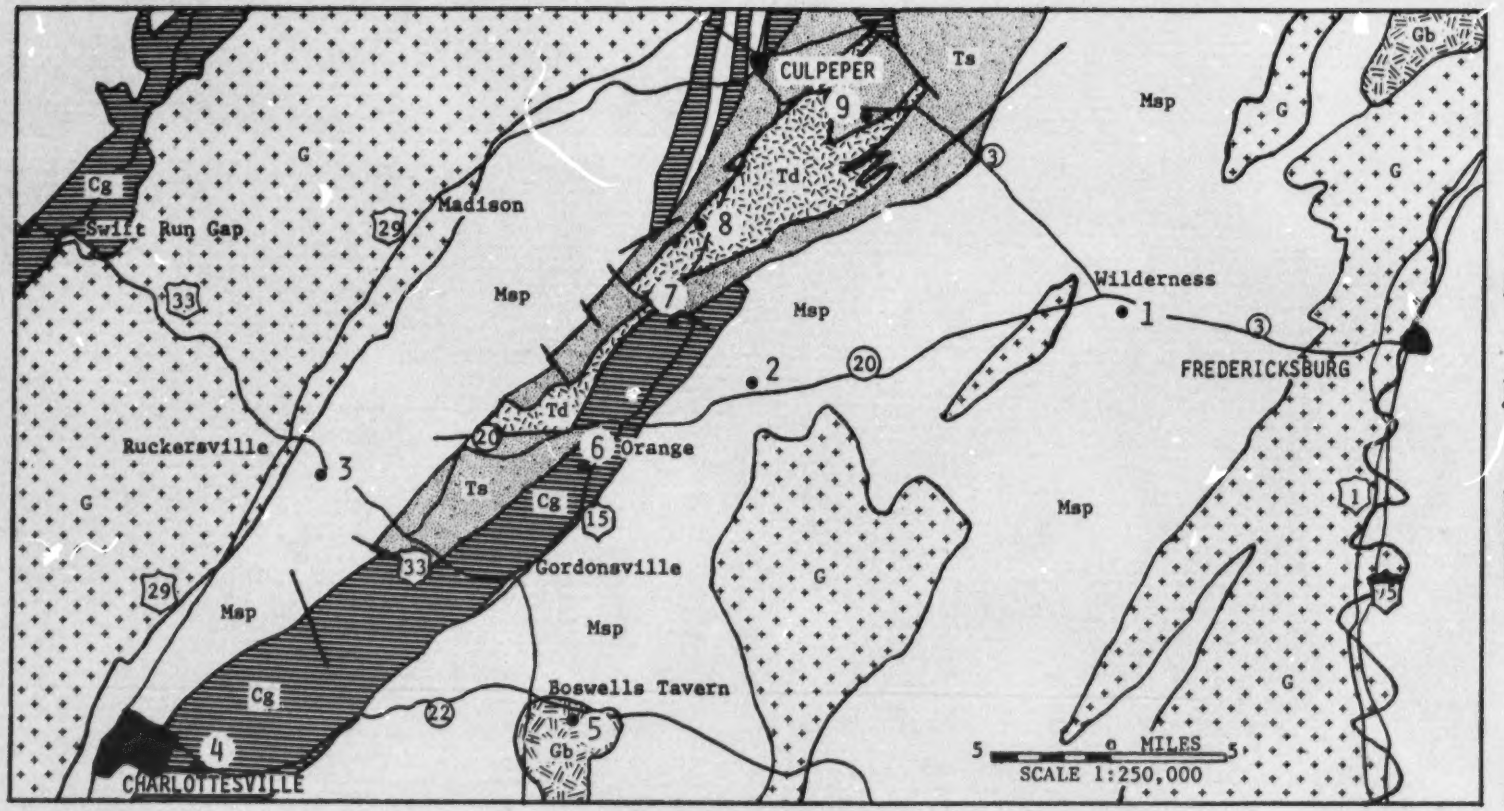


FIGURE 1 GEOLOGIC MAP OF THE CENTRAL PIEDMONT OF VIRGINIA

Td TRIASSIC DIABASE

Ts TRIASSIC SILTSTONE AND SHALE

Gb GABBRO

Cg CATOCTIN GREENSTONE

Msp METAMORPHIC ROCKS, PRINCIPALLY SCHIST AND PHYLLITE

G GRANITE AND GNEISS

•1 FIELD TRIP STOPS

FIGURE 1 GEOLOGIC MAP OF THE CENTRAL PIEDMONT OF VIRGINIA

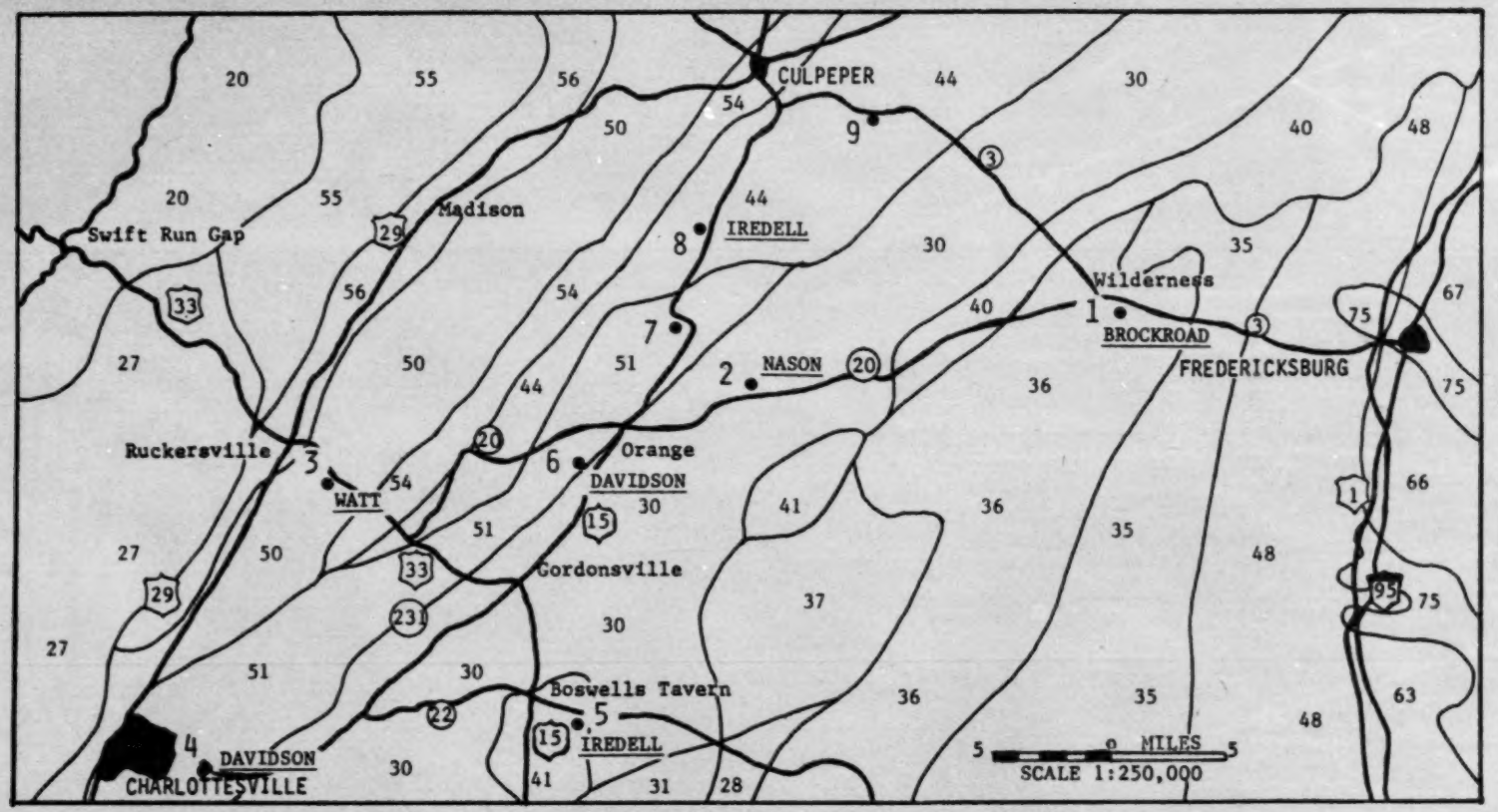


FIGURE 2 SOIL ASSOCIATIONS FOR THE CENTRAL PIEDMONT OF VIRGINIA
LEGEND OF SOIL SERIES ASSOCIATIONS

20 ROCKLAND-PORTERS-CATOCTIN
27 HAYESVILLE-BRANDYWINE(VAR.)-CULLIN(VAR)
28 CECIL-APPLING-MADISON
30 NASON-TATUM-MANTEO
31 GEORGEVILLE-TATUM-GOLDSTON
35 CECIL-PACOLET-WEDOWEE
36 NASON-TATUM-CATHARPIN
37 MADISON-GROVER-ASHLAR
41 IREDELL-ZION-POINDEXTER
44 BUCKS-PENN-KLINESVILLE
48 APPLING-SPOTSYLVANIA-FACEVILLE
50 ELIOAK-HAZEL-GLENELG
51 RABUN-DAVIDSON-MYERSVILLE
54 FAUQUIER-CATOCTIN-MYERSVILLE
56 CECIL-CULPEPER-LOUISBURG
63 SUFFOLK-UDULTS-OCHREPTS
66 EMPORIA-TETOTUM-BOURNE
67 KEMPSVILLE-BOURNE-SUFFOLK
75 PAMUNKEY-ALTAVISTA-FLUVAQUENTS

●1 FIELD TRIP STOPS

FIGURE 2 SOIL ASSOCIATIONS FOR THE CENTRAL PIEDMONT OF VIRGINIA
LEGEND OF SOIL SERIES ASSOCIATIONS

One final note for students of history: This stop is located on the ground where the Battle of the Wilderness took place in May, 1864. It was the first meeting of Generals Grant and Lee and was the scene of some of the most fierce fighting of the Civil War.

Cumulative Mileage	Point to Point Mileage	
12.7	0.4	Return to Rt. 3 and turn left (west) onto Rt. 3
13.9	1.2	Turn left and proceed west onto Rt. 20
31.2	17.3	**STOP 2 NASONS, ORANGE COUNTY**

Nason and Tatum Soils—The Nason and associated Tatum Soil Series are the most common soils in the Virginia Piedmont. They are residual soils formed from the underlying schist and phyllite. At this location, the bedrock is a micaceous schist. The phyllite and schist are believed to be metamorphosed sedimentary rocks of Paleozoic Age.

The Nason has a surface layer of grayish-brown silt loam and a subsoil of yellowish-brown silty clay loam. The Tatum soil is very similar to the Nason but exhibits a deeper red color in the subsoil.

Land Use Implications—The Nason and Tatum soils are highly acidic with a pH in the 3.5-4 range and with low natural fertility. Acidic conditions increase the solubility of aluminum in the soil. Since aluminum is highly toxic to many plants, acid and aluminum tolerant species, such as chestnut oak, white oak, huckleberry and pine, predominate on the Nason and Tatum soils. Both the Nason and Tatum, because of the silty texture, are very susceptible to erosion when disturbed by plowing or construction activities.

Because of the acidity, low natural fertility, and the erosive nature of the Nason and Tatum soils most of the area underlain by these soils is either forested or limed and used for pasture or other crops requiring little or no cultivation.

Cumulative Mileage	Point to Point Mileage	
		Proceed west on Rt. 20 through the town of Orange
48.7	17.5	Turn right onto Rt. 33
51.8	3.1	Turn left onto Rt. 644
51.9	0.1	**STOP 3 EHEART, ORANGE COUNTY**

Watt Soil—The Watt Soil Series forms over graphitic schist of the Johnson Mill and Lynchburg formations. The graphitic schist is basically a micaceous schist with several percent graphite which turns the rock a shiney gray to black color. The graphite occurs as irregular bands and stringers within the schist. The source of the carbon in rocks mapped as Precambrian is an interesting aspect of these formations.

In profile, the surface layer of the soil is a dark gray silt loam about 6 inches thick. The subsoil is generally an olive-gray to dark gray silt with up to 40 percent fragments of graphitic schist. Depth to bedrock ranges from 1.5 to 3 feet.

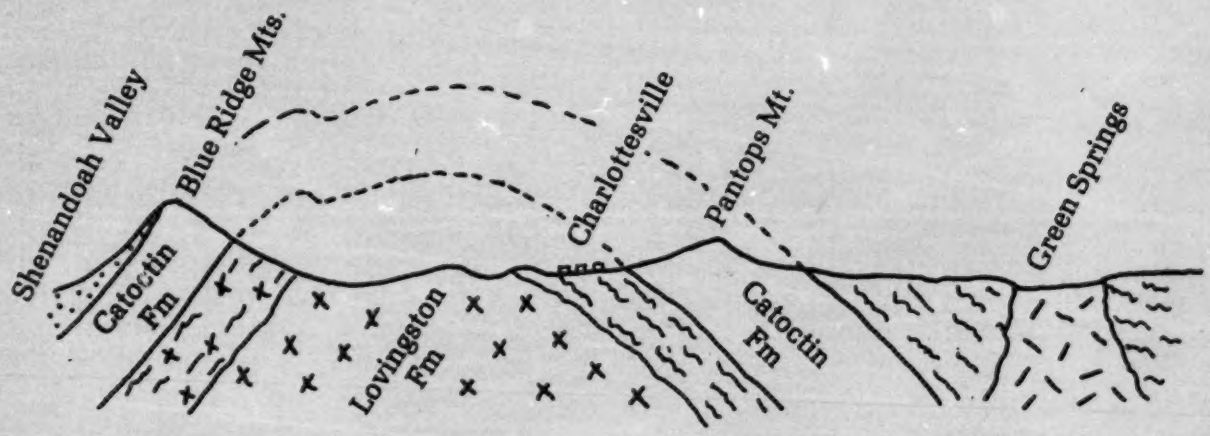
Land Use Implications—The Watt Soil Series is among the most acidic of Virginia soils, ranging down to a pH of one. Natural fertility is low and the soil is droughty and highly erosive. These negative factors make the Watt Series poorly suited for agriculture. Over 80 percent of the area underlain by Watt soil in Virginia is in forests, its best and most practical use.

Cumulative Mileage	Point to Point Mileage	
52.0	0.1	Return to Rt. 33 and turn left (west)
55.7	3.7	Turn left onto Rt. 29
69.4	13.7	Turn left onto Rt. 250 By-pass
72.6	3.2	Turn right onto new street to State Farm Insurance Co. Regional Office
72.9	0.3	**STOP 4 PANTOPS MOUNTAIN**

Pantops Mountain is a part of the eastern ridge of the Blue Ridge Anticlinorium. This ridge is underlain by the Catoctin Greenstone which reappears at the crest of the Blue Ridge Mountains some 20 miles to the west (see drawing page 22).

Cumulative Mileage	Point to Point Mileage	
73.2	0.3	Return to Rt. 250, turn right and proceed east across approximately 5 miles of Catoctin Greenstone.
76.5	3.3	Turn left onto Rt. 22. Note the contrast in land use on the Davidson-Rabun soils found on the greenstone on the left and the acid soils on the schists and phyllites on the right. LUNCH STOP—At Grace Episcopal Church. This beautiful churchyard is the scene of the "Blessing of the Hounds" held

Cumulative Mileage	Point to Point Mileage	
		each fall. Fox hunters of the Keswick Hunt Club and their hounds take part in this colorful and historic event.
81.9	5.4	Bear right and remain on Rt.
		22. Note the dramatic change in land use from agricultural to almost totally forested.
90.9	9.0	Turn right onto Rt. 638
91.7	0.8	**STOP 5 GREEN SPRINGS**



BLUE RIDGE ANTICLINORIUM

JAMES RIVER SYNCLINORIUM

Rocks exposed in the eroded anticlinorium between Pantops and the Blue Ridge underlie the Catoctin Formation and are older than the Catoctin. This entire sequence is mapped as Precambrian age. The Lovingston Formation, a granite gneiss, is the oldest formation exposed and is generally referred to as the basement rock for this part of the Virginia Piedmont. Rocks exposed east of the Pantops Mountain lie within the James River Synclinorium. These rocks, mainly schists and phyllites, overlie and are younger (Paleozoic age) than the Catoctin Formation. It is into these formations that the gabbro responsible for the unique character of the Green Springs area has intruded.

Iredell Soil—Iredell is the major soil series in the Green Springs area. It formed by the weathering of the underlying hornblende gabbro, a basic igneous rock which intruded into the surrounding schists and phyllites. The Iredell comprises a fairly thin profile of marked constrasting horizons. The topsoil is grayish brown silt, the subsoil is a very heavy, gray, impermeable clay, and the lowermost horizon is a granular saprolite.

Land Use Implications—The Iredell soil in its uncultivated state is only slightly acid and has a high natural surface area and low permeability. These factors have contributed to a long and prosperous agricultural history for the Green Springs area. Notes from a late eighteenth century diary refer to the waving fields of grain seen at Green Springs. Today as in the past the Green Springs area is largely cleared of forests and is intensively farmed. Agriculture appears to be the best use of the Iredell and related soils because the heavy clay subsoil and low permeability pose severe limitations to urban and commercial development.

The discovery of commercial deposits of vermiculite in the Green Springs area may have a profound effect on future land use. Plans are now underway to mine the vermiculite by open pit methods. Some local citizens are vigorously contesting the mining operations.

Cumulative Mileage	Point to Point Mileage	
		Continue south on Rt. 638
93.3	1.6	Turn right onto Rt. 617. Note famous Green Spring on left after which this region derived its name.

Cumulative Mileage	Point to Point Mileage	
95.9	2.3	Turn right onto Rt. 15. Pass Hawkwood, considered by many architects as the finest example of Tuscan architecture in America.
112.2	16.6	**STOP 6 SOUTH OF ORANGE COURTHOUSE**

Davidson Soil—The Davidson Soil Series is the major soil developed on the Catoctin greenstone. The iron in the greenstone oxidizes to a dark red color when the rock is weathered. The Davidson is a very well drained soil with moderate natural fertility and acidity. In places, it is very deep with a solum up to tens of feet in thickness. In its natural state, the Davidson supports good stands of desirable timber, such as black walnut, yellow poplar, pine and oak.

Land Use Implications—The Davidson is one of the best of the Piedmont soils for both agriculture and urban development. The very deep soils found along the flanks of the greenstone ridge through central and northern Virginia support some of the finest cattle and horse farms in the state. Pasture and hay crops, such as alfalfa, are particularly well suited to the Davidson. This high suitability for agriculture has resulted in widespread, intense use of the Davidson for farming. Much of the cleared land along the flanks of the greenstone ridge (Figure 3) are underlain by Davidson soil.

In addition to its excellence for agriculture, the Davidson is a prime soil for construction. Its compaction and load-bearing characteristics are superior for structures requiring shallow foundations. This dual excellence for the Davidson has resulted in high land values.

Cumulative Mileage	Point to Point Mileage	
		Continue north on Rt. 15 to town of Orange
113.2	1.0	Turn left onto Rt. 615 in Orange
120.0	6.8	**STOP 7 WADDELL CHURCH**

The Waddell churchyard offers a good view of the Triassic basin to the north. The church is located on Catoctin greenstone which is topographically higher than the floor of the basin. Clark Mountain to the right (facing north) is also composed of greenstone. The Rapidan River in the foreground approximately follows the fault contact between the greenstone and the Triassic basin. The basin itself is floored by both Triassic sedimentary rocks and diabase which has intruded into the sedimentary rocks. Buzzard Mountain (twin peaks) in the middle ground is composed of diabase.

Cumulative Mileage	Point to Point Mileage	
122.5	2.5	**STOP 8 BUENA BLACK GRANITE QUARRY**

Iredell Soil—Soil over the diabase intrusion belongs to the same series as that over the gabbro at Green Springs. Note the sticky nature of the clay subsoil. This poorly drained Iredell soil is known as "Black Jack Soil" by the local inhabitants.

Land Use Implications—Despite the similarities in the soils here and at Green Springs, the land use is quite different. At Green Springs these soils have been cleared and intensively farmed. Here the area has been left largely in scrub woods. The reason for this can be summed up in one word "drainage". At Green Springs, drainage is reasonably good; here it is very poor. The soils in this area are low lying, impermeable and remain wet much of the year. Septic tanks, basements and road foundations are beset with severe problems. Consequently, land is inexpensive and only lower socio-economic families are likely to locate here.

Buena Black Granite Quarry—Disbase is being quarried at two nearby sites. It is used for ornamental purposes, mainly tombstones. The material is taken out in large blocks and shipped by rail to Georgia for cutting and polishing. The diabase is well suited for these operations because it has a shallow soil cover and few joints. The diabase is predominantly composed of augite and plagioclase feldspar and exhibits subtle flow structures.

Cumulative Mileage	Point to Point Mileage	
		Continue north on Rt. 615
125.4	2.9	Turn left onto Rt. 522
129.1	3.7	Turn right onto Rt. 3
132.8	4.7	**STOP 9 CULPEPER STONE COMPANY QUARRY**

The quarry produces crushed stone from gently westward dipping Triassic sedimentary rocks comprised mainly of siltstone. Contact metamorphism of the siltstones by nearby diabase intrusion has produced a physically resistant rock similar to hornfels. In addition, epidote pods, sulfides and zeolites can be found locally within the quarry. Other geologic features of interest in this quarry include a thin freshwater limestone and well preserved dinosaur tracks. The freshwater limestone occurs as a thin white bed a few inches in thick-

ness. The rock is relatively pure calcium carbonate with an oolitic texture. Recent exposures of dinosaur tracks show numerous three toed imprints approximately 8 inches in length and 3 feet apart on selected bedding surfaces. Some bedding surfaces contain tracks in such numbers that studies of the "social behavior" of dinosaurs have been attempted.

Cumulative Mileage	Point to Point Mileage	
159.2	26.4	Proceed southeast on Rt. 3 to the Fredericksburg Sheraton Inn

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SEDIMENTARY PALEOENVIRONMENTS AND THE PALEOZOIC EVOLUTION OF THE APPALACHIAN GEOSYNCLINE IN THE NORTHERN SHENANDOAH VALLEY

by
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The Appalachian Mountains, and the geosyncline which formed them, are by any standard old. Yet for all their age and present quiet beauty these mountains and the forces which created them are not unique. Indeed, extending far into the Precambrian, back before the Appalachians were even a glimmer, the record of earth history shows that the cycle of mountain building is itself ancient. Rocks from North America alone give evidence of several successive major mountain ranges, extending as far back as 3.5 billion years, which criss-crossed and bordered the continent. Our study of the Appalachians take on significance, therefore, not so much because they are unique mountains, but because they may give us insight into the general processes of geosynclinal mountain building.

Reconstructing the history of geosynclines and the mountains which result is one of the most complex geologic tasks. It begins with the study of local geology where not only are the environmental conditions which produced each rock interpreted, but also the sequence of changing environments seen from rock unit to rock unit. Broader interpretations of regional geology require detailed studies of both stratigraphy/structure and the genetic significance of rocks, where ultimately it becomes necessary to squeeze from each rock all the evidence it contains. Finally, all this knowledge must be synthesized with plate tectonic theory for only here will a unified picture begin to emerge.

Briefly summarized below is a history of the Appalachian geosynclinal cycle in Virginia, synthesizing much of what we know about its history. This history, and the interpretations given for each stop on the field trip, are provided so that the significance of each individual rock can be understood, both in terms of the local processes which formed them, and also in terms of the evolving geosyncline and plate tectonic activity.

The earliest evidence in Virginia bearing on the Appalachian geosynclinal cycle is found in the late Precambrian Grenville Age granite and granodiorite batholiths found in the Blue Ridge Mountains. Although these rocks are not involved directly in the evolution of the Appalachian geosyncline they are important for they provide evidence of the appearance of eastern North America just preceding the birth of the Appalachian geosyncline.

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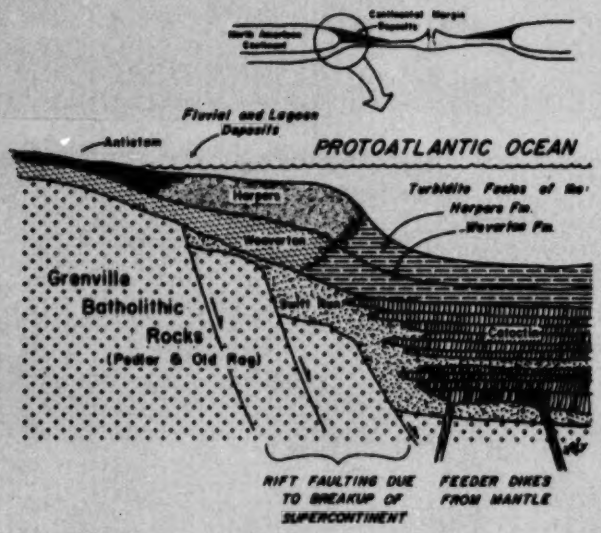
The granite batholiths of Grenville age were produced during the culmination of a major Precambrian geosynclinal mountain building cycle along the eastern edge of North America approximately 1.2 billion years ago. In terms of plate tectonic theory, such conditions arise when two crustal plates, each carrying a continent, converge until continental collision occurs. With collision the mountain range is built to its greatest heights while the intense structural deformation, regional metamorphism and granite batholith formation welds the continental masses together forming a "supercontinent". By latest Precambrian or earliest Cambrian time, however these Grenville mountains had been long since eroded to near sea level (a peneplain) and one could walk dry shod from North America across a region of relatively low relief to the adjoining continental mass (possibly, but not necessarily Africa). It is at this stage that the Appalachian geosynclinal cycle begins.

GEOSYNCLINAL CYCLE STAGE I— CONTINENTAL MARGIN DEPOSITION

The geosynclinal cycle begins when the "supercontinent" of North America and Africa (?) formed during the Grenville orogeny begins to rift apart in latest Precambrian time. Rifting produces a graben-like rift valley bounded on both sides by normal faults. Extensive volcanism accompanies the faulting and thick flood basalts fill the valley floor, much as is occurring in the East African and other rift valleys today. In North America remnants of these basalt flows are seen as the Catoctin greenstones (metamorphosed basalt) lying on top of the Grenville batholiths in the Blue Ridge Mountains. As the late Precambrian rifting continued, however, the rift valley widened and filled with sea water forming a Proto-Atlantic ocean, and the zone of active rifting moved away from the continental margin, stopping volcanic activity there, but creating a midoceanic rift (ridge) system in the newly



formed and widening ocean. Climbing up the rock record in Virginia we see this change when the Catoctin basalt lava flows disappear and are replaced by the clastic continental margin sediments of the lower Cambrian Chilhowee Group (see illustrations on pages 32 and 33). These quartz rich sediments were derived from weathering and erosion of the Grenville granite batholiths still exposed along the eastern edge of the continent. The Chilhowee Group rocks are marine and represent both beach/nearshore deposits (Stop A, Antietam Fm.) and continental slope turbidites (seen best in North Carolina although some rocks of this environment exist in Virginia).

Clastic continental margin deposition, much like that occurring along the North American east coast today, dominated the lower Cambrian, but by middle Cambrian time depositional conditions began to change. Throughout the Cambrian a major epicontinental (epeiric) sea transgressed across the North American continent, eventually covering it almost completely with water (the Sauk Sequence). Transgression drowned the rivers supplying the sands and shales, slowing, and finally stopping clastic deposition. With the supply of clastic sediment shut off, and a general tropical environment present (the equator ran north-south through eastern North America at this time) a long period of extensive carbonate deposition began. These conditions are represented by the Shady, and Elbrook through Lincolnshire Fms. They are all shallow water (supertidal, tidal, lagoonal, and shelf) carbonate deposits, excellently represented by the Beekmantown and New Market/Lincolnshire Fms. (Stops C and D, pages 34 and 36). Sometime during the deposition of these carbonate rocks, however, changes were occurring elsewhere which were eventually to have a profound effect on the east coast depositional environments.

GEOSYNCLINAL CYCLE STAGE II—ISLAND ARC FORMATION AND FLYSCH DEPOSITION

Although the middle Cambrian through lower Ordovician formations are dominated by shallow water carbonate deposition, scattered here and there through these rocks are found beds of bentonite—weathered volcanic ash (Stops C and D, pages 34 and 36). These ash deposits were derived from volcanic islands developing off the North American east coast. In terms of plate tectonics, the mid-oceanic rifting which had created the proto-Atlantic ocean stopped spreading, reversed its direction, and began closing. The causes of this reversal are not known, but the closing created a subduction zone; in essence, oceanic crust was forced down into the mantle under the eastern edge of the North American continent. Heat generated along the subduction zone created the volcanic island arc system. For a long time the only evidence of the change in plate motion and resulting subduction was the occasional volcanic ash deposits in the Cambrian and lower Ordovician carbonates. By middle Ordovician time, however, the changes were becoming dramatic for subduction not only created the volcanic island arc, but also dragged the eastern zone of shallow water carbonate deposition down into a deep water Eugeosynclinal basin where it filled with clastic sediment derived from the eastern island arc. Sediments deposited under these and similar conditions are typically graywacke turbidites and are collectively known as FLYSCH. It is this evidence which defines Stage II. Dramatic evidence for these changes can be seen in the Tumbling Run section of Stop C, page 34. Here in one long roadcut we see a change from the supratidal carbonate deposition of the New Market Fm., to the shelf deposits of the Lincolnshire Fm, to the deep water/basinal deposits of the Oranda and Edinburg Fms. Further evidence of the dramatic changes taking place during Stage II are in the combined Edinburg-Martinsburg Fms. Careful examination of the Edinburg Fm. shows that it is composed of alternating black limestones and shales. The black color (and H_2S smell on a broken surface) indicates deep water reducing conditions, but careful examination of the limestones also shows the presence of graded bedding. The limestones in the Edinburg Fm. are interpreted as turbidite deposits derived from the shallow water shelf environments to the west, being deposited in a rapidly subsiding basin to the east. The shales, on the other hand, are the most distal portions of the clastic turbidites derived from the island arc to the east (see illustra-

tion on page 36). The clastic portion, however, really represents the first and most distal turbidite influxes of the overlying Martinsburg Fm. Following the Edinburg Fm. the Martinsburg Fm. will eventually build a thick succession of graywacke turbidites (flysch) filling the basin. The Martinsburg, Fm. represents the first time in many hundreds of millions of years that clastic sediments of this immaturity have been deposited on this part of the continent.*

GEOSYNCLINAL CYCLE STAGE III—MAJOR MOUNTAIN BUILDING AND MOLASSE DEPOSITION.

With deposition of the Martinsburg Fm. two major turning points are reached in the evolving geosyncline. First, the increasing influx of graywacke turbidites eventually overruns and stops the carbonate deposition which had been continuous since the middle Cambrian. Second, a period of major mountain building begins. Mountain building in the Appalachian geosyncline took place in three separate pulses, or orogenies, the TACONIC (late Ordovician), ACADIAN (late Devonian), and APPALACHIAN (Pennsylvanian and Permian).

Both the Taconic and Acadian orogenies took place principally in the eastern (Eugeosynclinal) portion of the geosyncline (the Piedmont region). It is believed, however, that the Taconic orogeny took place during subduction while the Acadian was the result of collision between North America and Africa. Nonetheless, the principal evidence of their existence and history is found in the thick sequences of sediment eroded from them and deposited on the western portions of the geosyncline (Miogeosyncline) and craton. Both orogenies produced a similar, distinctive and characteristic cycle of sedimentary rock deposits by which we recognize and study them. These sediments eroded from the mountains built in the eugeosyncline and deposited on the adjoining miogeosyncline and craton are collectively known as MOLASSE*.

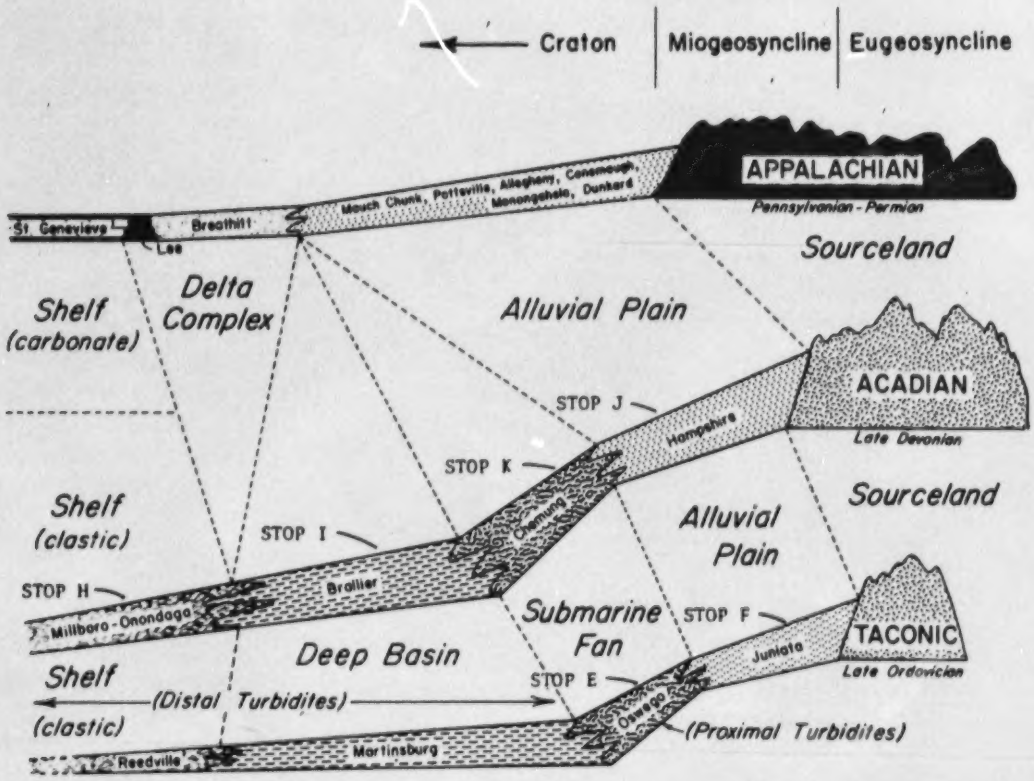
The mountain building cycle (illustration, page 29.) begins with pre-mountain building shallow water carbonate deposition. Abundant carbonates form best in the absence of clastic sediments and the extensive limestone deposits of the Lincolnshire and earlier formations preceding the Taconic orogeny, and Tonoloway and Helderberg Fms. preceding the Acadian orogeny are signs that mountain building had not yet begun. In both orogenies, however, the limestones are overlain by basinal gray/black shales and sandstones; the distal clastic turbidites eroding from either the Taconic island arc or the newly rising Acadian mountain source-land. As mountain building continues the third unit, grayish/green submarine fan sandstones and shales (proximal turbidites) begin to fill the depositional basin. In time the basin is filled and the marine environment is replaced by the red sandstones and shales of the alluvial plain which build westward. By this time, however, mountain building is beginning to wane and the supply of clastic sediment slows in volume and rate of influx. As a result the stream carried and beach agitated sands are worked longer and longer, becoming cleaner and more mature (i.e. quartz becomes more and more important until it is virtually the exclusive mineral present in the sediments). Climbing up section this change can be easily seen as the red color of the alluvial plain environment slowly diminishes and the sands become whiter and more mature. The fifth unit in the mountain building cycle, therefore, consists of beach/fluvial clean quartz sandstone and conglomerates.

In a stratigraphic section these rock units are, of course, seen stacked one on top of the other, but in reality at the time of deposition they all existed simultaneously side by side as shown in the illustration below. With time each of these environments grows outward into the depositional basin, covering the sediments deposited below and prior to it. (Actually the fifth unit does not form until the end of the mountain building cycle. Only when the mountain has been considerably eroded is the sea able to transgress back across the land laying down the beach deposit of clean quartz sand). The sequence of formations representing each orogeny is shown on pages 29, 32, and 33. We will examine the evidence for these mountain building cycles in some detail on this trip, particularly the New Market/Lincolnshire/Edinburg (Stop C),

* Maturity is a relative measure of how close the composition of a sandstone is to the most stable state it can reach, pure quartz sand. Until now, in the Appalachian Geosyncline, clastic sediments were quartz rich and near maturity. Graywacke is a very immature sandstone, poorly sorted and containing abundant angular grains of many rock and mineral fragments other than quartz. The sudden appearance of this rock, in marked contrast to the carbonates below, and after so many hundreds of millions of years, is a sign of the great changes about to take place.

* The terms FLYSCH and MOLASSE were coined during studies of European geosynclinal sediments. Since then they have been twisted and redefined so many times their original, and subsequent meanings are a welter of confusion. They are useful and well entrenched terms, however, so we will use them in the simple and narrow way they are defined here. This leads to a paradox, for the Edinburg and Martinsburg Fms. of the Taconic orogeny are flysch while the Oswego, Juniata, etc. Fms. directly above them are molasse. The simplest, and most simple minded, distinguishing difference is that the flysch sediments came from the Island Arc and were principally *deposited in* the Eugeosyncline, while the molasse was *eroded from* the major mountain ranges built in the eugeosyncline. There are other differences, and much room for discussion and differences of opinion.

Oswego (Stop E), Juniata/Tuscarora (Stop F), Massanutten (Stop B). Tonoloway/Wills Creek (Stop C), Onondaga (Stop H), Brallier (Stop I), Chemung (Stop K), and Hampshire (Stop J) Formations. Detailed interpretations of each unit are given with each stop description.



Sedimentary deposits produced by the Appalachian Orogeny are not found in the Shenandoah Valley; instead they are present extensively in West Virginia, Pennsylvania, Ohio, Kentucky, and Tennessee. The reason for this is that the Shenandoah Valley was part of the Appalachian mountain building and was thus a supplier, not a receiver of sediment. The intense folding and faulting seen on this trip, and which produced the Valley and Ridge provence, were produced during this orogeny.

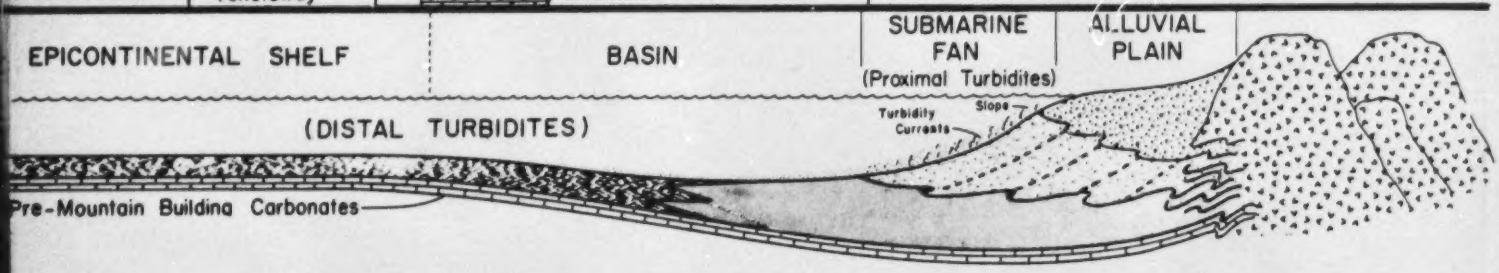
GEOSYNCLINAL CYCLE STAGE IV—ISOSTATIC ADJUSTMENT OF THE BATHOLITH

The plate tectonic convergence and collision which was responsible for the Taconic, Acadian, and Appalachian orogenies was also responsible for closing of the proto-Atlantic ocean and creation of the supercontinent Pangaea. The circumstances were, no doubt, very similar to those which existed during the formation of the Grenville mountains in the late Precambrian. Now, with mountain building completed in the Appalachian geosyncline, the final processes begin.

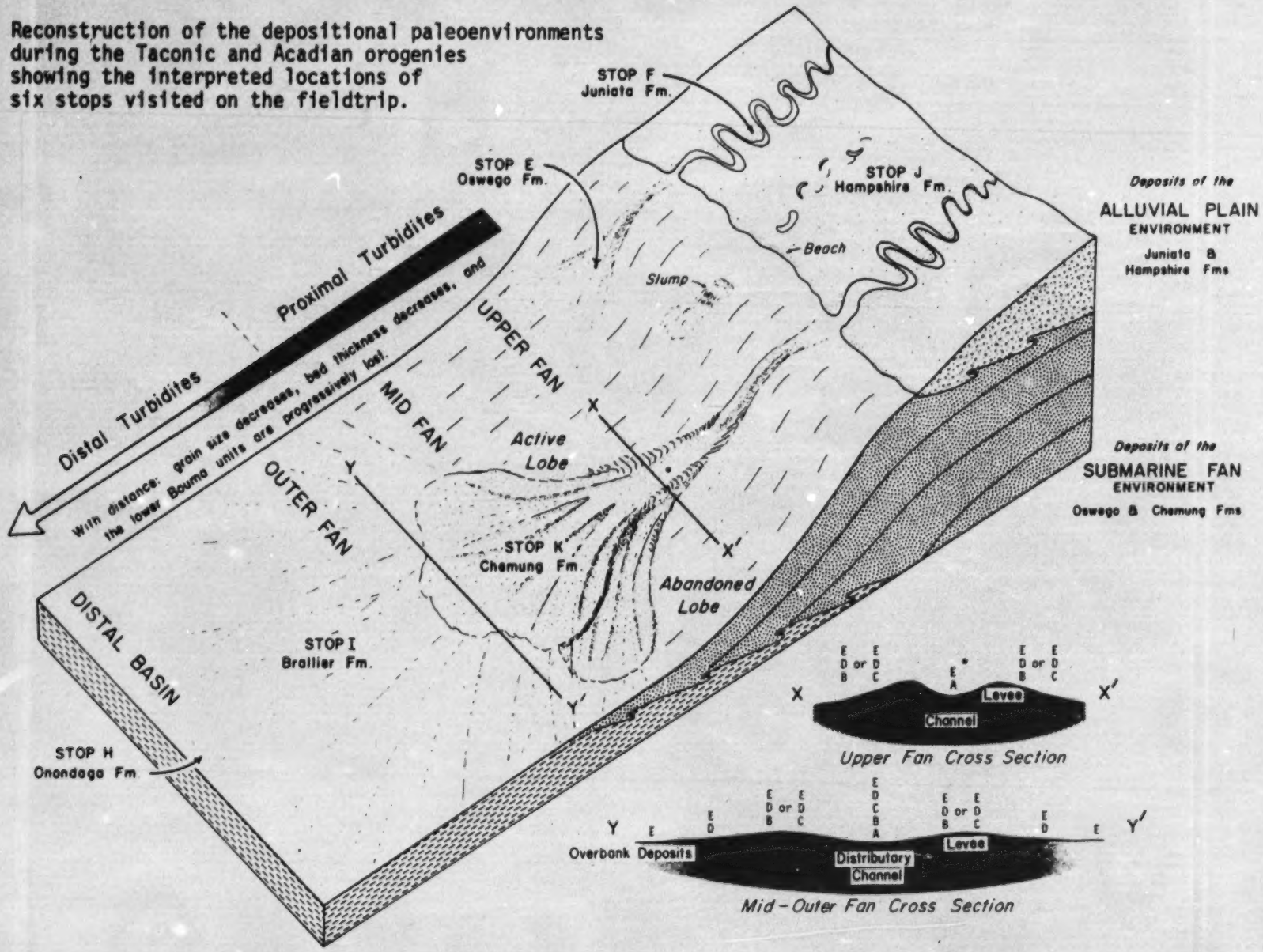
During subduction a thick wedge of relatively light weight sedimentary rocks in the eugeosyncline was dragged deep into the earth (10-20 km). Mountain building converted the deeper portions of this sediment wedge into regional metamorphic rocks and granite batholiths. Without subduction, however, there is nothing to hold this light rock down and it begins to rebound back up, much like a cork held under water and released, albeit much slower. Rebound is accompanied by weathering and erosion, and these two processes work in tandem over many millions of years until the "roots" of the old geosyncline are exposed and brought into isostatic equilibrium. At the present time we are witnessing the final stages of this isostatic adjustment which marks the end of the geosynclinal cycle. The Virginia Piedmont is now directly underlain by the regional metamorphic and granite rocks produced during the mountain building stage.

TACONIC and ACADIAN MOUNTAIN BUILDING CYCLE

Local Section			Lithology	Environmental Interpretation
TACONIC	ACADIAN			
Helderberg Tonoloway	Greenbrier	1	CARBONATE ROCKS	CARBONATE DOMINATED SHORELINE (Cycle Begins Again)
Tuscarora (Massanutten)	Pocono	5	**CLEAN QUARTZ SANDSTONES** TUSCARORA: Supermature, well sorted rounded, frosted grains. Beach environment. MASSANUTTEN: angular, poorly sorted quartz; fluvial cross bedding. POCONO: quartz sandstone and conglomerate. Fluvial.	**BEACH/FLUVIAL** End Of The Mountain Building Cycle. Sourceland is now nearly completely eroded. Sediment influx into the depositional basin is greatly slowed, and is mostly "lag" quartz sands. ("Lag" because quartz, the most resistant mineral, "lags" behind after everything else is weathered and eroded.) The slow influx and large quartz content allow the sediments to mature producing clean quartz sandstones and conglomerates. Environments are stream carried sediments (fluvial) washing off the low sourceland, and beach denosits laid down by the sea transgressing across the peneplained sourceland.
Juniata	Hampshire	4	**RED SANDSTONES and SHALES** JUNIATA: Thin to medium (1 to 12 in.) sandstone and shale beds. Sandstone quartz rich; cross bedding minor. HAMPSHIRE: Thick sandstone and shale beds. Cross bedding large and common Feldspar and mica common. Plant frags	**ALLUVIAL PLAIN** Accumulating directly next to the sourceland these rocks were deposited by numerous small rivers which drained the mountain highlands to the east. The alluvial plain was probably long, narrow, and sloped gently toward the basin to the west. With time, as the mountain grew, the alluvial plain built westward over the lower environments. Near the top of the local section the red color slowly diminishes as the sands increase in maturity. Environments are still fluvial but the sourceland is diminishing in elevation
Oswego	Chemung Brallier	3	**GRAYISH-GREEN SANDSTONES and SHALES** OSWEGO: Massive lithic sandstones and graywacke; congl. in places (pebbles of chert, shale, and limestone. CHEMUNG: "Dirty" sandstone, medium to thick bedded; current marks common At top red beds, fluvial cross bedding and ripple marks common.	**SUBMARINE FAN** Because the depositional basin subsided rapidly in the Taconic and Acadian the transition from Deep Basin/Shelf to Alluvial Plain was abrupt. Sand and gravel washing off the alluvial plain accumulated precariously on the edge of steep, nearshore, underwater slopes. Periodically these sediments slumped into the basin as coarse turbidity currents forming thick (one to many feet) sandstones alternating with thin shales. As these deposits fill the basin the environments change from marine to terrestrial. Because the transition from deep water environments to terrestrial environments is abrupt the zone of transitional environments (e.g. beach) is narrow and not easily found in the rock record.
Martinsburg Edinburg	Millboro Onondaga	2	**GRAY/BLACK SHALES and SANDSTONES** Shales dominant at bottom. EDINBURG graptolitic with black limestone. ONONDAGA calcareous, fossiliferous. Sandstones 1 to 12 inches. Graded bedding, current marks. MARTINSBURG: graywacke. BRALLIER: "dirty" s.s.	**BASIN/EPICONTINENTAL SHELF** (DISTAL TURBIDITES) The first influx of sediment from a newly rising sourceland. Black shales represent the clays deposited most distally in a turbidity flow. In time, as the turbidity deposits build outward, the shales give way to numerous alternating beds of sand and shale. Near the sourceland the environment is a rapidly subsiding geosynclinal basin (eugeosyncline) but westward grades into an epicontinental shelf. Slowly the sandstones become thicker and coarser and the shales thinner as the submarine fan approaches.
Lincolnshire (and earlier)	(Oriskany) Helderberg Tonoloway	1	**CARBONATE ROCKS** TACONIC: Micrites and dolomites. TONOLOWAY: Micrites and dolomites. HELDERBERG: Calcarenites, cherts.	**CARBONATE DOMINATED SHORELINE** Pre-Mountain Building Stage. Very low sourceland nearby or at great distance. In either case, little or no clastic sediment is being supplied to the depositional basin.



Reconstruction of the depositional paleoenvironments during the Taconic and Acadian orogenies showing the interpreted locations of six stops visited on the fieldtrip.



*Sands in the Upper Fan or Mid Fan channels may be deposited by a number of transportation mechanisms, including: Debris Flows, Grain Flows, Fluidized Sediment Flows, and Turbidity Currents.

© [illegible] L.S. Fichter, D.L. Poche'

Yet again, if we look at it from a different perspective we might consider this final step actually a Stage I of the next mountain building cycle, for the geologic conditions are not really too different from those which existed 600 million years ago at the beginning of the Cambrian. Continental Margin Deposition is taking place, and an Atlantic ocean basin is widening along a mid-oceanic rift. But with only a change in plate motion from divergence to convergence, much as must have happened at least twice in the past, the entire cycle may begin once again.

ROAD LOG AND FIELD TRIP STOP DESCRIPTIONS AND INTERPRETATIONS

Although this fieldtrip as originally scheduled will depart from Fredericksburg, Virginia, the roadlog below will begin just outside Luray, Virginia at the junction of Rt. 340 (which runs north-south through Page valley) and Bypass Rt. 211 (which runs east-west from Warrenton, Virginia to New Market, Virginia). This locality is conveniently near the first stop, and for persons tracing this trip at a later date Rts. 340 and 211 are the most likely access roads to Luray. Directions to each stop have been printed in reduced type not only to [illegible] also to set them off from the sto[illegible] terpretations.

DIRE[illegible] GROUP A: The itinerary begins at the juction[illegible].0 and 211 near Luray, Virginia. The mileage fi[illegible] on the bridge where Rt. 211 passes over Rt. 340[illegible] his point travel 3.15 miles east on Rt. 211 (toward the Blue Ridge) to juction with Rt. 611. Rt. 611 turns right (south) and is a small road easy to miss (a white house is on the right corner and a craft house on the left). Follow Rt. 211 1.7 miles until it enters Rt. 667: turn left on Rt. 667 and drive 1.1 miles.

Exposure is a small quarry tucked at the base of the hill to the left (north) side of Rt. 667. It is not easily visible from the road, being hidden by woods, but can be reached by a short, obscure road. The quarry is in float so no outcrop *per se* is visible. Travel distance 6 miles. Travel time 15 minutes.

STOP A—ANTIETAM FM. (CHILHOWEE GROUP) LOWER CAMBRIAN. OBSERVATION TIME 15 MINUTES

The Antietam is a clean quartz sandstone (quartz arenite) converted to a quartzite by metamorphism. Because this quarry is cut into float no outcrop *per se* is present to examine. Many float fragments, however, have one or more straight, parallel "tubes" of discoloration about the size of a pencil known as *Scolithus* burrows.

Interpretation: Beach/Near Shore environment. Stage I—Continental Margin Deposition. *Scolithus* is a beach/near shore trace fossil and places these rocks in that depositional environment. The beach/near shore interpretation is also supported by the great maturity of the sands. They were derived from weathering of the Grenville batholithic granites to the west and deposited along the shore of the proto-Atlantic ocean which had just recently opened due to plate tectonic rifting (see illustration, page 26). With time the sediments built out into the ocean creating a thick wedge of shelf sediments, much like that on the east coast today. In time these sediments will be thrust up into the Taconic Mountains to be reeroded and deposited westward (Stops B, E, and F).

DIRECTIONS TO STOP B: Retrace Rts. 667 and 611 back to Rt. 211. Turn left (west) on Rt. 211 (toward Luray) and drive 3 miles to junction with Rt. 340. Follow Rt. 340 north (right) through Front Royal, crossing the long bridge over the South Fork of the Shenandoah River (25.7 miles). Immediately turn left (west) on Rt. 55 toward Strasburg. Follow Rt. 55 west 5.2 miles to junction of Rt. 678 at Waterlick. Turn left (south) on Rt. 678 toward Fort Valley, 1.9 miles.

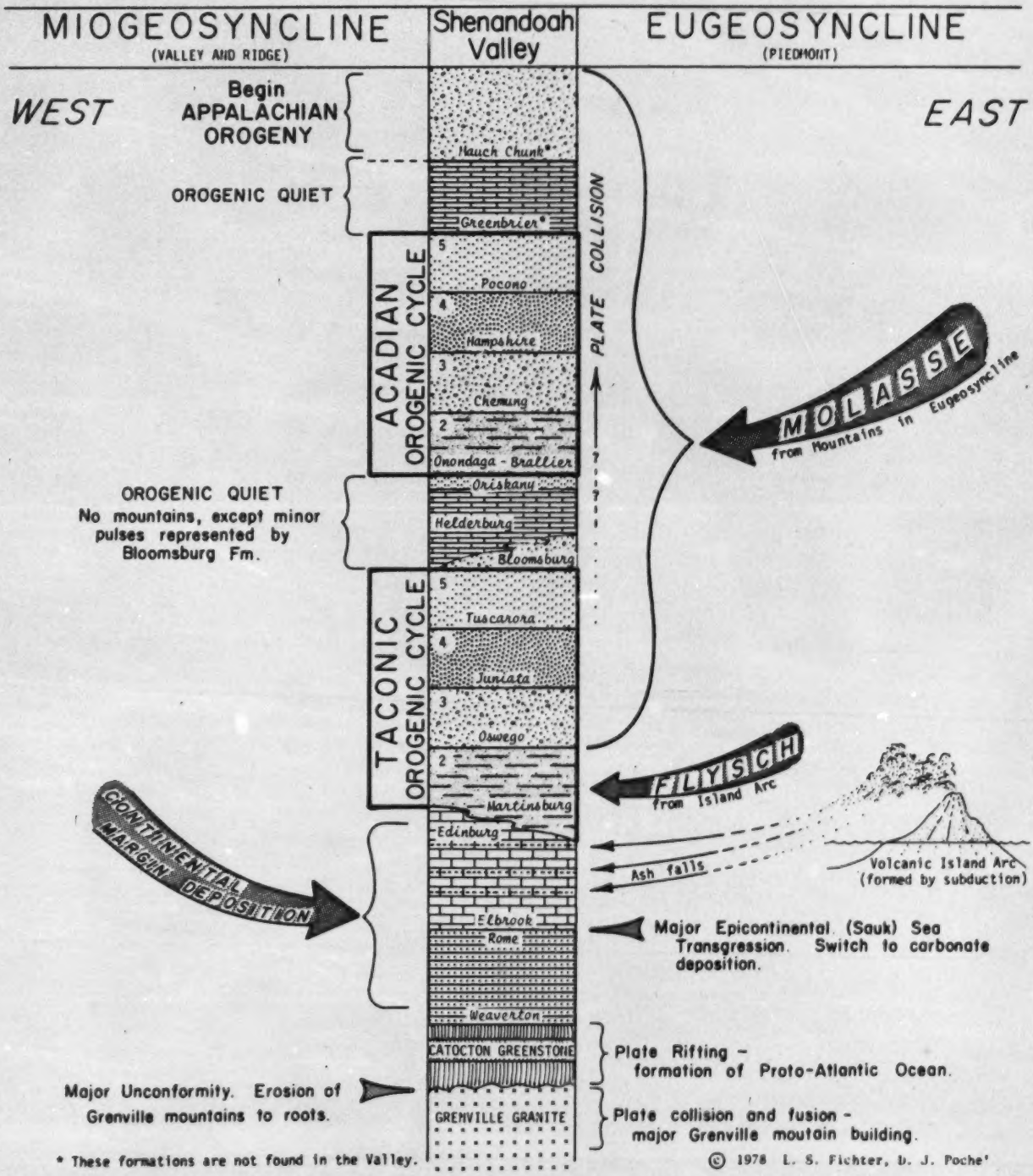
Exposure is a watergap (road cut) on the right (west) side of the road leading into Fort Valley within the Massanutten synclinorium. The outcrop is a shear cliff of white sandstone. A place to park can be found about 100 yards south of the exposure on the right side of the road at the base of a large talus pile of boulders. Travel distance 30.9 miles. Travel time 1 hour.

STOP B—MASSANUTTEN FM. SILURIAN. OBSERVATION TIME 30 MINUTES.

The Massanutten is a clean quartz sandstone (quartz arenite) which under a handlens shows poorly rounded/sorted grains. Large scale crossbedding is abundant in the roadcut, and the tops of some excellent trough cross beds are visible on a large block of float just south along the road. Along the northern half of the roadcut, near the base, are thin shale partings containing fragments of the oldest known vascular plants.

Interpretation: Fluvial (river)/Alluvial Plain environment. Stage III—Major Mountain Building; end of the Taconic mountain building cycle. These sands are the last sediments deposited from the nearly completely eroded Taconic mountains and are an eastern facies of the Tuscarora Fm. to be seen at Stop F. To a large degree these sands were derived from the Stage I Continental Margin clastic sediments which had been thrust up by the compression of subduction to form the Taconic mountains. The fluvial nature of the deposit is demonstrated by the abundant trough cross bedding and presence of plant fragments. The great angularity of the sand grains implies they have not been transported far and are quite near the Taconic sourceland. This supposition is supported by the large unconformity (not directly seen at this stop) between the Martinsburg Fm. and the Massanutten

Geologic History of the Shenandoah Valley As Preserved in the Local Section



Summary Stratigraphy of the Central and Northern Shenandoah Valley

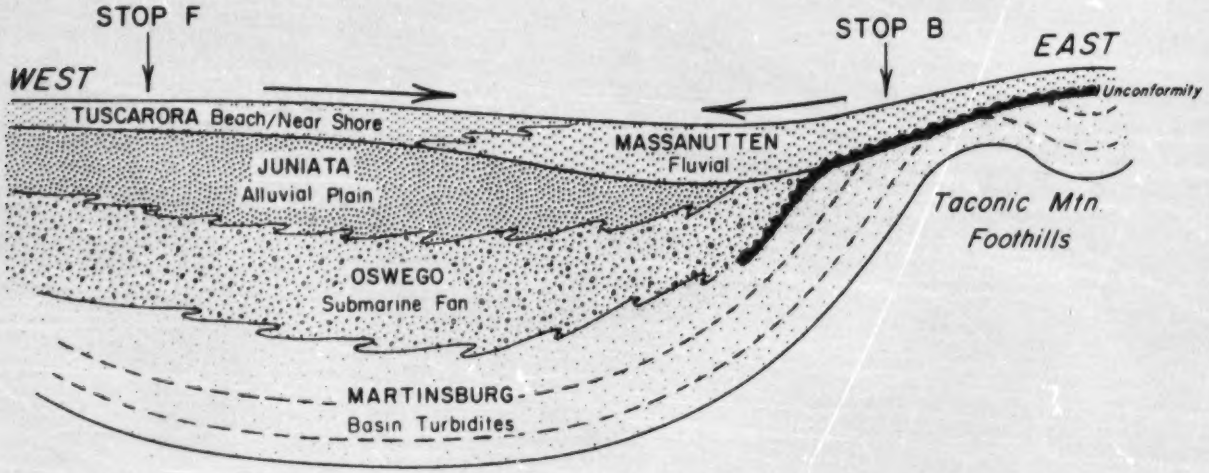
		FORMATION	THICKNESS		DESCRIPTION		
KASKASKIA	MISS.	Mauch Chunk	Not present northern Virginia		S.S. coarse, channels. SILT/SH gray/blk, plant foss abndt in places. COAL	Molasse	
		Greenbriar			L.S. (micrite, calcar, oolite) some qtzitic, gray (red in places), Foss common		
		Pocono	300-1700		S.S. qtz, gray/white, coarse, thick bed, x-bed, little SH. CONGL (qtz) in places.		Acadian Orogeny
	DEVONIAN	Hampshire (Catskill)	2000		S.S. red, thick bed, arkosic, mica, x-bed, plant frag. MUDST red, thick bed.		
		Chemung	2000		S.S. med/thick, med gr, gray/grn. SH grn, soft CONGL (qtz) & S.S./SH (red) scat thru-out		
		Braillier (Portage)	1500-1700		S.S. (fine, black)/ SH thin/med, olive, weath tan, cur marks/trace com, foss rare.		
		Millboro (Used south of Shendandoah Co.) — Mahantango	900		MAR: SH dk-gray/blk, fiss, weath silver-gray, dwarf foss, pyrite. MAH: Bot-Mid: SH/SILT, grn, thin. Top: S.S., fine, mass/thk, fos may be abn		
		Millboro — Marcellus	350-550				
		Tioga Bentonite	80-100		SH/SILTS gray interbedded with TUFF calc.		
		Onondaga (Needmore)	100-530		SH silty, olive, weath nonfiss, chalky, yellowish, bot very foss, grades into Marcellus		
		Regional Unconformity. In S.W. Va. Onondaga lies on Martinsburg					
		Oriskany (Ridgley)	10-125		S.S. qtz, coarse to congl, calc (friable) or SiO_2 cement , white/gray/tan, foss mod/abndt		
	SILURIAN	Helderburg Group — New Scotland	70-150		KEYS: L.S. gray, weath brn bot-wht top, fine/med, foss abndt. NEWCRK: L.S. gray, coarse, crinoidal. NEWSCOT: L.S. dk-gray, med grain, abndt foss, CHERT white/black, massive.		
		Helderburg Group — New Creek (Cosymans)	17-50				
		Helderburg Group — Keyser	70-600				
		Tonoloway	50-250		L.S. argill, gray/yellow, fine lam, mud crks, F.P. congl, ostra abndt. Interbed with Keyser		
		CAYUGA — Wills Creek	60-150		BLOOMS: S.S./SILT/SH red/grn, s.s. w/ Fe_2O_3 cem WILLS CRK: SH, sandy/silt, calc, yellow/brn w/ L.S. gray/red, foss (ostra, bryo, brach)		
		CAYUGA — Bloomsburg	0-400				
		CAYUGA — McKenzie	0-75		SH calc, yellow, fossils (esp ostracods)		
		CLINTON — Keefer	70	700-1200	MASS: S.S. qtz, white, locally CONGL & thin blk SH, trough cross-bed abndt. TUSC: Bot qtz CONGL; Top QTZITE white, thick. ROSE HILL: SH sandy, yel-brn; S.S. fine/med, gray/brn, red S.S. at top, abndt foss in places. KEEF: QTZITE gray/white, cross bed, base grn/purp SH		Taconic Orogeny
		CLINTON — Rose Hill — Massanutten	650				
		CLINTON — Tuscarora (Clinch)	50-250				
	ORDOVICIAN	Juniata — Local Unconformity in Massanutten Mtn.	0-200		S.S./SH red, choc, white; S.S. fine/med, thin/thick; Cross bed in thick S.S.		
		Oswego	0-375		S.S. med/thick, coar, green/gray, brown weath CONGL in places. Scat thin red S.S. beds.		
		Martinsburg	3000		Bot: L.S. blk + METABENT. Mid S.S./SH alter gray/green, rust weath. Top: S.S. Sparce foss.	Flysch	
		Oranda	40-60		Very var: SILTST gray, calc; SH blk; MUDSTO calc; L.S. gray, nodul. Ext foss. METABENT.		
		Local Unconformity					
		Edinburg	425-600		Var, gen L.S. nodular weath, thin/med, dk-gray/blk; SH blk, thin; Foss abundant.		
		Lincolnshire	25-170		L.S. dk gray, med/coarse, med/thick; CHERT blk, bed; Foss beds common, lt gray. Top nodular.		
		New Market	40-250		Bot: Basal carb/chert congl, thin bed L.S. abov Top: L.S. fine, blue, weath white, thick bed.		
		Regional Unconformity					
		Beekmantown (Rockdale Run)	2000-2500		DOLO thk bed, fine gr, lt-dk gray, L.S. blue-gray. CHERT black, white. Foss com. Many stru		
		Chepultepec (Stonehenge)	500		L.S. thick bed, blue, fine, crinkly weath. DOLO rare. F.P. Congl, Oolites. Rare foss but widesp		
	CAMBRIAN	Conococheague	2500		L.S. blue-gray, lam; DOLO lt gray, mass, fine; S.S. qtz. *Stroma.*, F.P. Congl, Few foss.		
		Elbrook	2000		L.S. blue-gray, yellow weath; DOLO laminated. Algal L.S. in top 300'.		
		Rome (Waynesboro)	2000		Very var. SH red/green; S.S.; DOLO granular; L.S. blue-banded. Scantily fossiliferous.		
		Shady	1600		DOLO granular; L.S. beds at top & bottom. Few foss except a few scattered l.s. beds.		
		CHILHOWEE — Erwin-Antietam	500-1500		S.S. qtz, fine/medium, thick/massive, gray, weathers white. *Scolithus* burrows.		
		CHILHOWEE — Hampton (Harpers)	2000		SH Thin-bedded, fine-grained and S.S. dirty. Rusty weathering. Metamorphosed.		
		CHILHOWEE — Weverton	800		S.S. qtz, coarse, massive and CONGL qtz, *alternating with* phyllitic SH. Many layers purplish		
		Regional Unconformity					
SAUK	PreC	Catoctin			Greenstone		

TIPPECANOE

Continental Margin Deposits

Fm., skipping the Oswego and Juniata Fms. (see page 33). This unconformity implies that the Massanutten Mountain and this part of the Valley were uplifted and eroded during the Taconic orogeny. Since the section below the Tuscarora to be seen at Stop F is complete, the mountain building must not have extended that far west. (see illustration, page 34).

What the Taconic mountains looked like would be pure conjecture, but the tentative appearance of the first vascular plants, which would soon bloom into a lush flora, came too late to relieve the barren landscape of this first Appalachian mountain range.



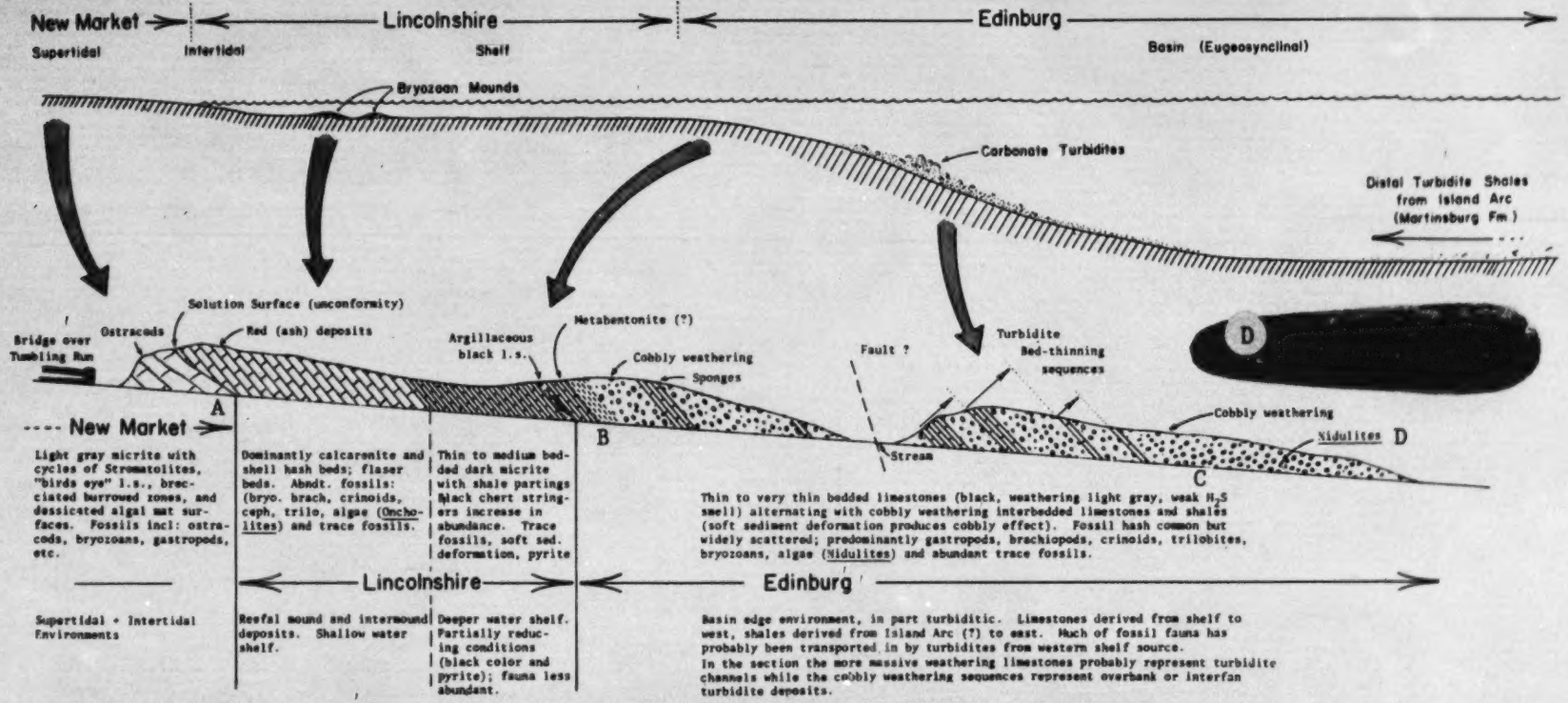
DIRECTIONS TO STOP C: Return northward on Rt. 678 toward Waterlick and Rt. 55. Turn left (west) on Rt. 55 toward Strasburg. At the first stoplight in Strasburg Rt. 55 bears sharply right; but continue straight through town on Rt. 11. About 1.5 miles south of Strasburg turn right on Rt. 601 and drive up the hill about .3 miles; park on pulloff on left.

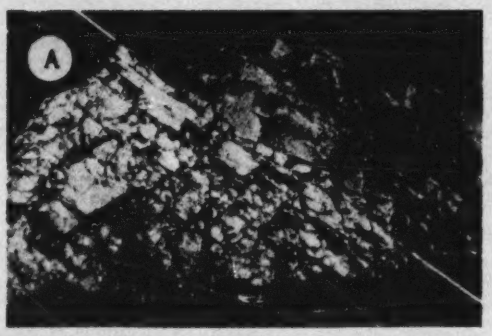
Exposure is a long roadcut running the length of the hill along Rt. 601. Travel distance 9.4 miles. Travel time 16 minutes.

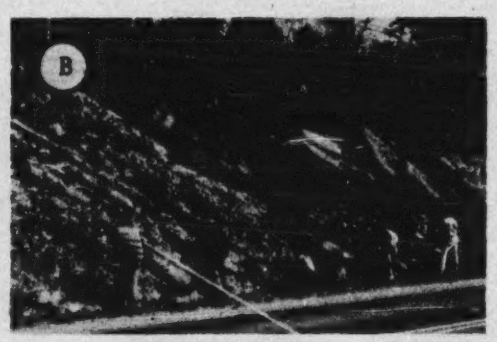
STOP C—NEW MARKET, LINCOLNSHIRE, AND EDINBURG FMS. ORDOVICIAN. OBSERVATION TIME 60 MINUTES.

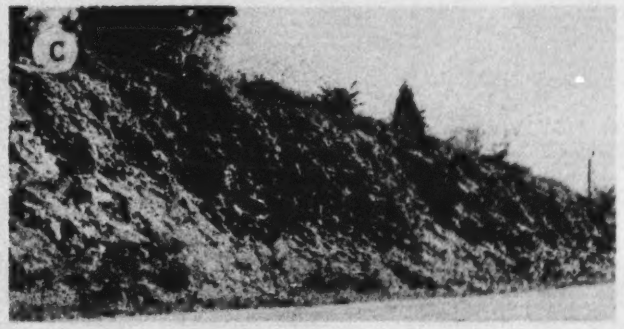
This is the classic and well known "Tumbling Run" section where most of the Ordovician carbonate formations of the Valley are exposed. We will examine only the middle of the sequence. There is so much exposed here to see that it is virtually impossible to generalize, even in outline, especially considering the limited amount of time available for us to examine it. We are going to break, therefore, from our normal format in this field guide and forego a list of the structures present in each formation. Rather on page 35 is an outline sketch of the roadcut on which is pointed out some of the major features present as well as their summary interpretation. This is accompanied by a generalized historical interpretation presented below. (Many of the interpretations presented here come from an indepth study of the section by Diana Lipp and David Poche, in progress at the time of this writing).

Interpretations: Transition from Stage I—Carbonate Continental Margin Deposition, to Stage II —Island Arc Formation, seen here as (Eugeosynclinal) basin subsidence and deep water carbonate turbidite and clastic (flysch) deposition. During the Ordovician this locality was in a critical position in the developing geosyncline. Throughout the Cambrian and lower Ordovician the area had been one of great tectonic stability. In the latter half of this period shallow water carbonate deposition predominated producing several thousand feet of shelf, tidal and supratidal deposits. The last of this carbonate sequence is seen in the New Market and lower part of the Lincolnshire Fms. The New Market represents intertidal + supertidal micrite deposition and is bounded on top by a small scale unconformity with some solution surfaces, produced during a low sea stand. The first several hundred feet of the Lincolnshire on top of the New Market are deeper water shelf deposits with evidence of bryozoan reefal mounds and abundant other organisms. This initial Lincolnshire sea was probably the result of transgression but other processes soon began to operate. The presence in the lower part of the Lincolnshire of red ash deposits imply that plate subduction along the east coast had begun, creating a volcanic island arc. The subduction, however, also began to drag the shallow water continental margin environments down into a deep (Eugeosynclinal) basin. The Tumbling Run section lay just along the western edge of this basin and walking up the Lincolnshire section pro-

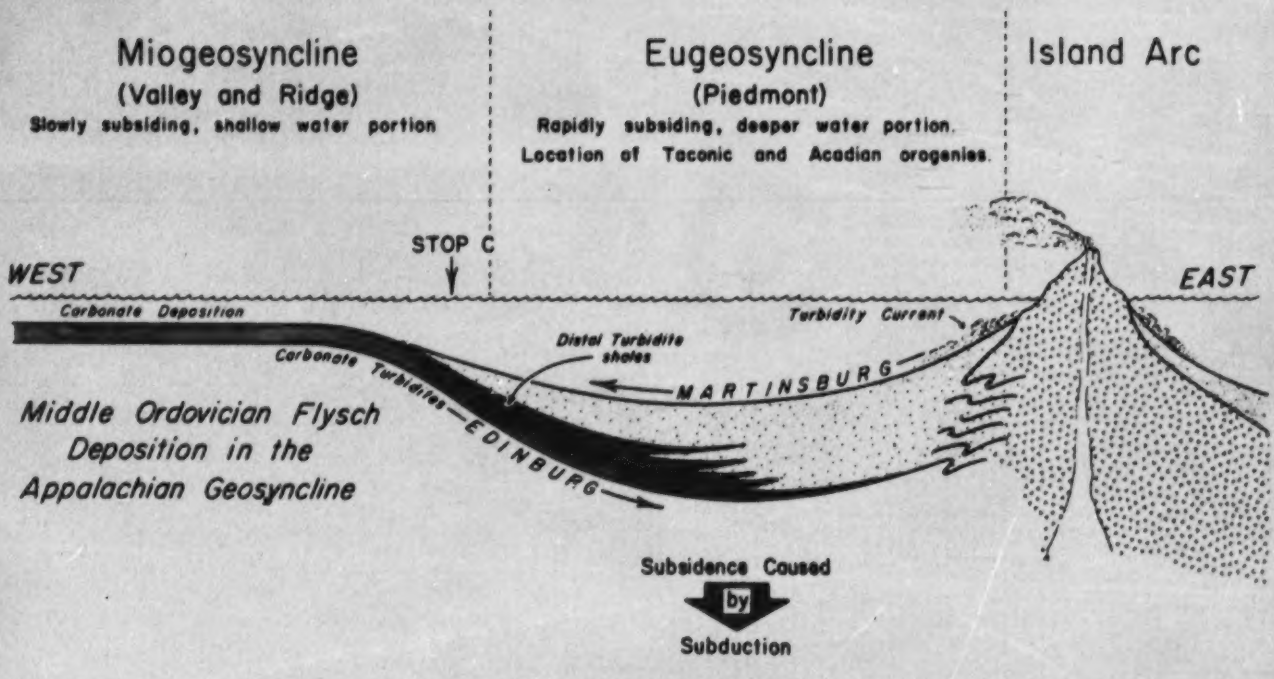

New Market
Lincolnshire
Edinburg
Supertidal
Intertidal
Shelf
Basin (Eugeosynclinal)
Bryozoan Mounds
Carbonate Turbidites
Distal Turbidite Shales from Island Arc (Martinsburg Fm.)
Solution Surface (unconformity)
Ostracods
Red (ash) deposits
Bridge over Tumbling Run
Argillaceous black l.s.
Metabentonite (?)
Cobbly weathering
Sponges
Fault ?
Turbidite Bed-thinning sequences
Cobbly weathering
Nidulites
Stream
A
B
C
D
New Market
Light gray micrite with cycles of Stromatolites, "birds eye" l.s., brecciated burrowed zones, and dessicated algal mat surfaces. Fossils incl: ostracods, bryozoans, gastropods, etc.
Dominantly calcarenite and shell hash beds; flaser beds. Abndt. fossils: (bryo. brach, crinoids, ceph, trilo, algae (Oncholites) and trace fossils.
Thin to medium bedded dark micrite with shale partings Black chert stringers increase in abundance. Trace fossils, soft sed. deformation, pyrite
Thin to very thin bedded limestones (black, weathering light gray, weak H2S smell) alternating with cobbly weathering interbedded limestones and shales (soft sediment deformation produces cobbly effect). Fossil hash common but widely scattered; predominantly gastropods, brachiopods, crinoids, trilobites, bryozoans, algae (Nidulites) and abundant trace fossils.
Lincolnshire
Edinburg
Supertidal + Intertidal Environments
Reefal mound and intermound deposits. Shallow water shelf.
Deeper water shelf. Partially reducing conditions (black color and pyrite); fauna less abundant.
Basin edge environment, in part turbiditic. Limestones derived from shelf to west, shales derived from Island Arc (?) to east. Much of fossil fauna has probably been transported in by turbidites from western shelf source.
In the section the more massive weathering limestones probably represent turbidite channels while the cobbly weathering sequences represent overbank or interfan turbidite deposits.







Summary of the geology present in the Tumbling Run Section (Stop C). ***Top:*** **Reconstruction of the depositional environments represented by each formation.** ***Middle:*** **Profile of the roadcut showing some of the major lithologic changes with generalized descriptions and interpretations below that.** ***Pictures:*** **(A) New Market-Lincolnshire contact at upper end of roadcut near bridge (white line). (B) Lincolnshire-Edinburg contact (white line). (C) Edinburg Fm. at lower end of exposure showing cobbly weathering. (D)** ***Nidulites,*** **an algal fossil commonly found in the lower end of the exposure (Edinburg Fm.)**



gressively deeper water sediments were deposited. The trend of continued deepening continued through the Edinburg Fm., and as well evidence of increasing tectonic activity in the island arc. This evidence consists of the increasing occurrance of metabentonite (altered volcanic ash) beds, the increasing shale content, and the development of turbidite deposits in the Edinburg. The increasing shale content was derived predominantly from the island arc to the east which, as it built higher and higher, shed increasing quantities of clastic sediment further westward. From the Edinburg Fm. alone this is not apparent but if we could continue up section to the Martinsburg Fm. we would see developed there the classic graywacke turbidites (flysch). The turbidite nature of the Edinburg Fm. is evidenced by the graded bedding present, as well as the cycles of bed thinning representing alternating turbidite channels and overbank deposits.

DIRECTIONS TO STOP D: Return to Rt. 11 and turn left (north) back toward Strasburg. In Strasburg turn left (west) on Rt. 55 and drive .2 miles, turning left again onto Rt. 55 west (this turn is just beyond a bridge overpass and is easy to miss). Proceed 4 miles to the junction of Rt. 623 to Mt. Olive.

Exposure is a small roadcut on the right hand side of Rt. 55 about 100 yards before its junction with Rt. 623. Travel distance 6 miles. Travel time 15 minutes.

STOP D—BEEKMANTOWN FM. LOWER ORDOVICIAN. OBSERVATION TIME 40 MINUTES.

Present at this stop are many features characteristic of the very thick Beekmantown Fm., as well as many sedimentary structures typical of the other carbonate formations above and below it, e.g. micrite (fine grained limestone), dolomite, chert, algal laminated micrite, algal stromatolites (some replaced by chert), load structures (soft sediment deformation), herringbone structures (tidal formed, bidirectional cross laminations), fecal pelletal limestones, abundant burrowings, flaser bedding (tidal formed mixed lenses of coarser and finer sediment), zones of red (volcanic ash) stain, stylolites (pressure solution lines), karst solution surfaces, and karst breccias.

Interpretation: Carbonate Tidal Flat, Intertidal and Lagoonal environments. Stage I—Continental Margin Deposition. By this point in time the clastic deposition of the first half of Stage I has been shut off by the Sauk epicontinental sea which had transgressed over eastern North America. The entire eastern continent was of very low relief and tides dominated large proportions of it. The strong tidal influence is demonstrated by many of the structures listed above, especially the algal laminates and stromatolites, dolomite, herringbone structures, flaser bedding, and karst solution surfaces. Cyclical transgressions of deeper water lagoonal environments over the tidal flat are indicated, however, by the beds of extensive bur-

Stage III—Major Mountain Building—Taconic Orogeny. Because the depositional basin subsided rapidly in the Taconic orogeny the transition from the deep basin (Martinsburg Fm.) to the alluvial plain (Juniata Fm.) was abrupt. Sand and gravel washing off the alluvial plain accumulated precariously on the edge of steep, nearshore underwater slopes and periodically slumped into the basin as coarse debris flows. These deposits closest to the ancient shoreline are the coarsest and are represented by the Oswego Fm. at this stop.

The composition of the Oswego Fm. (and Juniata directly above it just up the road) contrast sharply with rocks representing similar environments in the Acadian orogeny (Chemung and Hampshire Fms.—see illus., page 29). The Oswego/Juniata are quartz rich, and the Oswego has many sedimentary rock fragments. The Chemung and Hampshire, on the other hand, have abundant mica and feldspar. The different compositions reflect different sourcelands. The Taconic sourceland was built to a large degree out of the Continental Margin Clastics (e.g. Anietam Fm., Stop A) and carbonate rocks (e.g. Beekmantown Fm., Stop D) of Stage I and thus have abundant quartz and sedimentary rock fragments such as chert. The sourceland for the Acadian Chemung (Stop K) and Hampshire (Stop J) Fms. was built of the regional metamorphic and granite batholithic rocks produced *during* the Taconic, and since these rocks are mica and feldspar rich, mica and feldspar can be seen in the sediments derived from them. The comparison is best made by collecting a piece of the Juniata Fm. from the next stop (F) to compare with the Hampshire Fm of Stop J.

DIRECTIONS TO STOP F: Continue west on Rt. 55 2.6 miles to the crest of the mountain. There is a dirt road entrance on the left (south) side of Rt. 55 to pull into. Exposure is a long, low roadcut on the right (north) side of Rt. 55. Travel distance 2.6 miles. Travel time 5 minutes.

STOP F—JUNIATA AND TUSCARORA FMS. UPPER ORDOVICIAN AND LOWER SILURIAN. OBSERVATION TIME 20 MINUTES.

The Juniata is a red, ferruginous, quartz rich sandstone which grades upsection into a pure, white, clean quartz sandstone (quartz arenite) (the Tuscarora Fm.). The Juniata is trough cross bedded (although it is difficult to see at this locality) with mud chip conglomerates. (Collect a piece of the Juniata sandstone for later comparison with the Hampshire Fm.) The Tuscarora is also cross bedded but has distinctive *Scolithus* trace fossils (as in the Antietam, Stop A). Careful study of the Tuscarora sand grains with a handlens will show a mixing of small, well rounded, frosted grains with larger, angular, clear grains.

Interpretation: Alluvial Plain environment (Juniata) grading upsection into a Beach/Near Shore environment (Tuscarora). Stage III—Major Mountain Building; end of the Taconic Mountain Building Cycle. As the cycle of mountain building comes to a close the supply of clastic sediment slows in volume and rate of influx. As a result stream carried, and beach agitated sands are worked longer and longer, becoming cleaner and more mature. Simultaneously the epicontinental sea begins to transgress (from west to east) across the eroded and near peneplained Taconic sourceland producing the transition from the Juniata alluvial plain to the Tuscarora beach/near shore environments. This transition is beautifully seen at this stop. (See illustration, page 34).

The Juniata alluvial plain interpretation is based on many exposures but is supported here by the cross bedding and mud chip conglomerate (a point bar or channel lag deposit). The Tuscarora beach/near shore interpretation is based on the presence of *Scolithus*, cross bedding, and maturity of the sandstones. The mixture of well rounded, frosted grains and clear, angular grains in the Tuscarora reflect two source directions for these sands. The angular grains come from the weathering of the old eastern Taconic mountain sourceland, and are really an extension of the Massanutten Fm. sands seen in Stop B. The rounded grains are multicyclic and were derived from the western craton. Farther to the west the Tuscarora is composed almost exclusively of the well rounded grains. So as we travel from east to west there is a steady change in the character of these quartz sands, and somewhere between here and the Massanutten Fm. at Stop B (to the east) there must be a transition from the Tuscarora's beach environment to the Massanutten's fluvial environment. (See illustration, page 34).

DIRECTIONS TO STOP G: Turn around and travel back down Rt. 55 (east) to junction with Rt. 608 (approximately 2.7 miles). Turn left (north) on Rt. 608 (a dirt road) and follow it approximately 2.7 miles to junction with Rt. 600. Turn left on Rt. 600 and follow it about .7 miles to junction of Rt. 606 (NOTE: the road here appears to go straight but Rt. 600 turns sharply left while Rt. 606 goes straight. Look for the junction of Rt. 600 and 606 and follow Rt. 600 sharply left). Eight point six (8.6) miles beyond the Rt. 600-606 junction Rt. 600 turns sharply left again but follow the road straight where it is now Rt. 614. Rt. 614 ends at Rt. 50 (a divided, four lane highway). Turn left on Rt. 50 and drive 2 miles.

Exposure is a low roadcut on both sides of Rt. 50. There is room to pull off on the right. Travel distance 15.5 miles. Travel time 35 minutes.

STOP G—TONOLOWAY AND WILLS CREEK FMS. UPPER SILURIAN. OBSERVATION TIME 30 MINUTES.

The Tonoloway Fm. on the eastern end of the roadcut is composed of gray micrites and dolomites, weathering gray and tan, with abundant algal laminates, large (6-12") dessication cracks, interformational conglomerates, ripple cross laminations (see illustration, page 40) and ostracod hashes, plus other microstructures. Toward the western end of the outcrop is the red Wills Creek Fm., a calcareous siltstone and mudstone.

Interpretation: (The Wills Creek is stratigraphically below the Tonoloway and has been brought up at this stop by faulting.) Carbonate Tidal Flat/Intertidal environment (Tonoloway Fm.) Stage III—Major Mountain Building; the calm between the Taconic and Acadian orogenies. The Tonoloway tidal flat/intertidal interpretation is supported most notably by the dessication cracks, interformational conglomerates, algal laminates, and dolomite. The ostracod fossil hashes and ripple cross laminations are typically shallow water, both supporting the environmental interpretation. This formation, thus, implies the absence of any clastic sourceland nearby.

Stratigraphically, however, the Tonoloway Fm. lies between the formations of the Taconic orogeny below and Acadian orogeny above. It is this evidence which tells us of the calm period in the Appalachian geosyncline between the Taconic and Acadian orogenies. That the calm was not perfect is evidenced by the Wills Creek Fm. at the western end of the outcrop.

The Wills Creek Fm. is a marine facies of the Bloomsburg Fm. The Bloomsburg Fm. represents an alluvial plain environment building westward from a small pulse of mountain building to the east. That this pulse was not a full mountain building cycle is evidenced by the lack of other environments of a typical Taconic or Acadian mountain building cycle. The red shales we see in the small piece of Wills Creek at this stop, however, reflects the influx of clastic sediment from this small "mountain building" pulse. Its effect was to stop carbonate deposition at this point in the geosyncline for a short period. (It actually just pushed carbonate deposition westward for a short period).

DIRECTIONS TO STOP H: Continue west on Rt. 50 a very short distance (.1 mile) to crossover to eastbound lane. Travel east 1 mile to junction of Rt. 600 at Millers Country Store (Shell station). Pull off on right side in store parking lot.

Exposure is a low roadcut on the corner of Rt. 50 and 600. It will be necessary to cross Rt. 50 to get to it. Travel distance 1 mile. Travel time 5 minutes.

STOP H—ONONDAGA FM. MIDDLE DEVONIAN. OBSERVATION TIME 20 MINUTES.

Olive, weathering silver-gray, fossiliferous, calcareous shale and siltstone. No visible structures, pencil weathering. Fossils include: trilobites, rugose corals, brachiopods, and cephalopods, among others.

Interpretation: Distal Turbidite shales (see page 30 for a pictoral location of this environment). Stage III—Major Mountain Building; Acadian Orogeny. Directly below this formation (just down the road to the west) is the pure, quartz Oriskany sandstone, and below that the widespread limestones of the Helderberg and Tonoloway Fms. (Stop G). These represent the Carbonate Dominated period of calm between the Taconic and Acadian orogenies. The sudden appearance of the shale in the Onondaga Fm. marks the abrupt end of this period of calm and the beginning of the Acadian orogeny to the east. The calcareous nature of this shale indicates that the transition from carbonate to clastic deposition is not yet complete; in southwest Virginia and New York-Pennsylvania the Onondaga is a pure limestone. From this point on, however, the depositional basin will subside rapidly and fill in with the pure clastic sediments to be seen at Stops I and J.

DIRECTIONS TO STOP I: Continue east on Rt. 50 1.3 miles. Exposure is a long, high roadcut on the west bound lane of the highway. Pull off on the right (there isn't much room) and cross the median strip to the outcrop. Travel distance 1.3 miles. Travel time 5 minutes.

STOP I—BRALLIER FM. MIDDLE DEVONIAN. OBSERVATION TIME 30 MINUTES.

Monotonously repetitious alternating beds of medium bedded sandstones and shales. Sandstones range from gray, to green, to red; shales varigated red and green. Current marks, parallel laminated, ripple cross laminated and massive bedded sandstones, and trace fossils are commonly seen.

Interpretation: Outer Fan Turbidites in a Deep Water Basin (see page 30 for a pictoral location of this environment). Stage III—Major Mountain Building; Acadian Orogeny. After the first influx of the Onondaga Fm. seen in the last stop changes in the geosyncline resulting from the Acadian orogeny were rapid. The depositional basin to the west of the mountains subsided rapidly and the volume of influxing sediment increased continuously producing a thick sequence of turbidity deposits. This long road cut is a typical and classic example of what turbidity deposits look like. Superficially, from a distance, the turbidite nature is characterized by the hundreds of monotonously alternating beds of sandstone and shale, but close

Idealized Bouma Turbidite Sequence

COMPLETE SEQUENCE

UNIT		DESCRIPTION
E		T_E Clays (shales) without structure. Lower contact gradational. Deposited in months to years.
D		T_D Parallel laminations in silts/ fine sands. Lower contact distinct. Deposited in hours.
C		T_C Ripples, cross laminations, contorted laminations in silt/fine sand. Lower contact sharp. Deposited in hours.
B		T_B Thick, parallel laminae of sand. Lower contact gradational. Deposited in minutes.
A		T_A Sandy or gravely; graded bedding from obvious to inconspicuous. Deposited in minutes.

CHANGES WITH DISTANCE →

LOWER UNITS DROP OUT WITH DISTANCE
BED THICKNESS DECREASES
GRAIN SIZE DECREASES

Submarine Sediment Transport Mechanisms

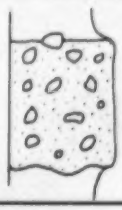
Four mechanisms for transporting sediment under water are now known. TURBIDITY CURRENTS, illustrated above, allows downslope flow because turbulence keeps sediment in suspension. The other mechanisms illustrated here also occur but may be hard to recognize because different transport mechanisms can exist in the same flow, and many structures form in more than one flow mech.

FLUIDIZED FLOW

Loosely packed sands become "fluidized" when water flows up and through it separating and supporting the grains. Such sands have little strength and behave like a fluid. Fluidized flows loose water and "freeze" from bottom to top forming dish structures, fluid escape pipes and/or convolute bedding.

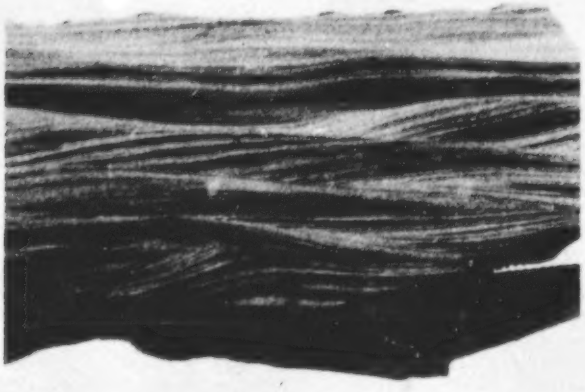
GRAIN FLOW

Some sediments loose cohesion because of grain to grain interaction. Moving downslope under gravity the grains remain dispursed by bouncing off one another. Grain flows are hard to recognize because few structures are restricted to them, except weak reverse graded bedding.



DEBRIS FLOW

Sluggish downslope movements of watery mixtures of clay, sand, and boulders in response to gravity (like wet concrete). Large boulders, up to several feet, can be rafted down low slopes. Deposition occurs by mass emplacement. Sandy debris flows (without pebbles or boulders) may be difficult to recognize.



Ripple Cross Laminations
(Appear as ripples on bedding surfaces; The Bouma T_C in turbidites, although these structures form in other non-turbidite environments, as seen at Stop G)

Current Marks (groove casts)
(Appear on sandstone bottoms of T_A, T_B, or T_C units, whichever is on the bottom of the sequence. Current marks may also be broad, shallow and/or bulbous with rounded upcurrent ends)

up there are numerous other diagnostic features. Most characteristic are the current marks frequently found on the bottoms of the sandstones. The commonly seen trace fossils, although not confined to turbidites, are frequently and diversely present. More evidence is found in the detailed structures of the rock units known as the Bouma sequence, the ideal sequence of units present in a complete turbidite deposit diagrammed on the previous page.

Complete Bouma sequences are only infrequently encountered and then only in particular environments (see illustration, page ..). Various partial Bouma sequences are common, however. At this outcrop the shales are T_E units; the "sandstones" include T_A, T_B, and T_C individually or in combination. Turbidity currents are only one mechanism for transporting underwater sediments; three additional transporting mechanisms are now recognized occurring principally in the inner and mid fan channels and they are diagrammed and illustrated below the Idealized Bouma Turbidite Sequence on the previous page. Most of the rocks at this stop are probably due to turbidity currents, but Stop K (Chemung Fm.) may include Grain Flows or Fluidized Flows, and Stop E (the Oswego Fm.) of course, was a debris flow.

DIRECTIONS TO STOP J: Continue east on Rt. 50 1.2 miles. Exposure is a large roadcut on both sides of the highway. There is a pull off on the east end of the outcrop. Climb the exposure along the east bound land to gain perspective of the opposite outcrop. Also search for structures on this side of the highway. Then cross the medium strip to examine the rocks along the westbound lane more closely. Travel distance 1.2 miles. Travel time 5 minutes.

STOP J—HAMPSHIRE FM. UPPER DEVONIAN. OBSERVATION TIME 30 MINUTES.

Red, maroon, and green, thick-bedded, mica and feldspar rich sandstone alternating with red mudstones. Sandstones are cross bedded and are of irregular thickness showing signs of channelization (as seen from across the road). Other characteristics seen at this stop in the past include: tree trunks, plant fragments, root system traces (?), mud pebble conglomerates (point bar deposits), asymmetrical ripple marks, trace fossils, and raindrop impressions (?).

Interpretation: Alluvial Plain (river channel, flood plain) environment (see page 30 for a pictoral location of this environment). Stage III—Major Mountain Building; Acadian Orogeny. Almost all the sedimentary structures listed above point to a terrestrial environment. Accumulating directly next to the Acadian sourceland these rocks were deposited by numerous small rivers which drained the mountain highlands to the east. The alluvial plain ran north-south and was long, narrow, and sloped gently toward the basin to the west. With time, as the mountain grew, the alluvial plain built westward into the basin and over the lower formations.

DIRECTIONS TO STOP K: Continue east on Rt. 50 .55 miles to crossover to the west bound lane. Park in the crossover. Exposure is a very long roadcut along the west bound lane. Travel distance .55 miles. Travel time 5 minutes.

STOP K—BRALLIER AND CHEMUNG FMS. MIDDLE DEVONIAN. OBSERVATION TIME 20 MIN.

On the east (right) side of this long roadcut are the numerous alternating thin to medium bedded sandstones and shales of the Brallier Fm. seen at Stop I. About half way down the outcrop a thick lens shaped body of strongly tough cross-bedded sandstone projects away from the rest of the exposure. Somewhere over the next 100 yards or so the Brallier changes into the Chemung. This is seen as an increase in thickness of the sandstones and shales and a change in color to red, gray, and green. Sedimentary structures and other features seen in the Chemung include tree trunks, common plant fragments, large pillow and ball structures (soft sediment deformation), trace fossils (sometimes extremely abundant), ripple cross laminations and ripple marks, and flute casts (current marks).

Interpretation: Outer Fan (Brallier) to Mid Fan/Inner Fan (Chemung) environments (see illustration on page 30 for a pictoral location of these environments.) Stage III—Major Mountain Building; Acadian Orogeny. The changes in this exposure, upsection, from right to left, and around the corner into the Hampshire Fm. of the last stop are some of the most dramatic in this part of the valley. On the right (eastern) end is the Brallier Fm. with the same outer fan turbidite interpretation as at Stop I. Interpreting the thick body of strongly cross bedded sandstone half way down the outcrop is a problem. Trough cross bedding is typically fluvial, but this is bounded above and below by turbidites. Tentatively we interpret it as a submarine fan distributary channel, but here the sediment was transported more by traction (stream bottom) than turbidite mechanisms, resulting in the trough cross bedding. From here up section to the end of the exposure the mid/inner fan environment progressively encroaches (builds outward into the basin) and the mix of fossils and structures in this outcrop must at first seem inexplicable, but they are really consistant with this environment. Flute casts are most typical of proximal turbidites. The ripple cross laminations and ripple marks are Unit C in the Bouma sequence (see

page 40). Trace fossils are very characteristic of turbidite deposits. The pillow and ball structures were caused either by slumping down the slope of the fan, or soft sediment deformation due to weight of overlying sediments; these are also common in proximal turbidite deposits. The tree trunks and plant fragments represent debris carried down to the sea by rivers and then into the deeper water environment by the turbidity currents. Likewise, the red sediments were transported in the same way. The Chemung Fm. lies stratigraphically below the alluvial plain Hampshire Fm. of the last stop, but at the time of deposition was also an offshore facies; the red sediments represent influxes of Hampshire, possibly during storm events. And just around the corner to the west is the Hampshire Fm. so somewhere between this outcrop and that outcrop the environments must change from submarine fan, to beach, to alluvial plain. This rapid change in environment and superficially confusing mix of fossils and sedimentary structures demonstrates the necessity for using all available evidence in interpeting ancient sedimentary rocks and the environments they represent.

REFERENCES

It is difficult in a half dozen or so references to select from all that is available. The following were chosen because they were pertinent to the geology or interpretations made on the trip or were of more general value in making depositional environmental interpretations. For interested persons their bibliographies will serve as the start of a literature search.

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USING COASTAL PLAIN STRATIGRAPHY NEAR FREDERICKSBURG, VIRGINIA AS A TEACHING TOOL

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Excellent, if sporadic, studies of Coastal Plain geology in northern Virginia, including Fredericksburg, have continued from Darton's (1896) short but accurate work to the current, detailed studies in progress by Mixon & Newell (1977, 1978). The paucity of fossils, complex facies relationships and thicknesses, lithologic similarity of many units, and the small number of good exposures make stratigraphic correlation difficult.

Beginning with the Spring semester of 1977, I initiated a regular-term field course on local Coastal Plain deposits in order to increase the interest and geologic maturity of our majors at Mary Washington College. The number of students enrolled in the course has doubled in the year since it began and the number of geology majors has shown a comparable increase. A large part of this new interest is attributable to this regular-term field course. The course requires large blocks of time for both students and faculty and perserverance and self-discipline. The rewards of the effort are increased self-reliance, powers of generalization and synthesis on the part of both students and instructor.

We have not progressed far enough in our work to give much in the way of general interpretation. Today's field trip consists of some observations and description at selected sites in the Fredericksburg area.

GENERAL GEOLOGY

The Piedmont geology in the area has been and is being intensively mapped by Louis Pavilides (1976) of the U. S. Geological Survey. We will visit parts of this complex igneous and metamorphic terrain where it is in faulted contact with sediments of Early Cretaceous age. The upper surface of the crystalline complex slopes irregularly seaward. Various drilling and geophysical investigations have established that the irregularity was caused by a combination of erosion, warping, and faulting.

The lowermost sediments (Potomac Group) in the Fredericksburg area are poorly sorted arkosic conglomerates and sands, quartzose, and micaceous, silts, and clays that intertongue and succeed one another in a complex pattern. Plant remains from muddy sand beds indicate an Early Cretaceous age for these deposits (Berry, 1912; Dorf, 1952; Brenner, 1963). These beds overlie the crystalline complex with profound unconformity and at their westernmost contact have been overridden at several localities by crystalline rocks along northeast trending, steep reverse faults. Some of these faults extend for as much as 20 miles. Vertical displacement at STOP 2 is about 120 feet (Mixon and Newell, 1978).

The Potomac Group is unconformably overlain by well sorted fine quartzose and glauconitic sands of Paleocene age (Aquia Formation). The Aquia is abundantly fossiliferous at many places in the area, including Belvedere Beach on the Potomac River (STOP 5). In the western part of the Fredericksburg Quadrangle the deposits are thin and unbedded, being well mixed by burrowing marine organisms. A persistent, thin, basal, quartz conglomerate marks the base of the Aquia Formation.

The Nanjemoy Formation of Eocene age is not represented in the areas we will visit (Table 1). The next formation is, instead, the lowest unit of the Chesapeake Group, the Calvert Formation, which in the Fredericksburg area consists of blocky clay succeeding a thin quartz conglomerate. The lower part of the Calvert Formation consists almost exclusively of diatom tests. This unit is not well represented in the Fredericksburg area. The uppermost deposits in the Coastal Plain are coarse gravels overlain and intermixed with sands and clays. The "gravels" consist of large, fair to well rounded cobbles, pebbles and boulders of several ages. These sediments, of probable Pliocene-Pleistocene age, occur at elevations of approximately 190-200 feet. A younger sequence of gravels occurs at about 140-145 feet and rests unconformably on the Potomac Group. Several other gravel deposits occur at lower levels as terraces along major streams and their tributaries. We follow the practice of several workers in calling the oldest and highest of these coarse deposits "upland gravels". The younger ones, we call Quarternary alluvium. Some would call these units Lafayette and Columbia Formations, respectively. The younger deposits

of sand and gravel are being extensively mined along the Rappahannock River below Fredericksburg. They are 15 feet or more thick and contain large boulders to 4 feet in diameter.

Figure 1 is a locality and road map of the study area.

Table I

STRATIGRAPHIC SECTIONS IN VIRGINIA AND AT FREDERICKSBURG

Series	VIRGINIA Formation	FREDERICKSBURG Formation
Quaternary	Various terrace deposits	Various terrace deposits
Plio-Pleistocene	"Upland Gravels"	"Upland Gravels"
Miocene	Yorktown Formation	
	St. Marys Formation	
	Choptank Formation	
	Calvert Formation	Calvert Formation
Oligocene		
Eocene	Nanjemoy Formation	
Paleocene	Aquia Formation	Aquia Formation
Upper Cretaceous		
Lower Cretaceous	Potomac Group	Potomac Group
Middle to Lower Paleozoic	Crystalline Complex	Crystalline Complex

DESCRIPTIONS OF STOPS

STOP 1. Burrow pit on property of W. L. Hicks, located just south of Rt. 17 Bypass on U. S. 1.

COMPOSITE STRATIGRAPHIC SECTION

(After Mixon and Newell, 1978)

Elevation (ft.)	Series	Formation	Lithology
225-195	Plio-Pleistocene	"Upland Gravels"	Coarse gravels and sand
195-181	Miocene	Calvert Formation	Silty clay with quartz pebbles at base
181-158	Paleocene	Aquia Formation	Bioturbidite of fine quartz sand and glauconite, with burrows
158-145	Lower Cretaceous	Potomac Group	Feldspathic sand with scattered gravels
145-35	Subsurface	Potomac Group	
35	Piedmont crystallines		

STOP 2. Hazel Run fault about 200 yards west of intersection of Hazel Run and U. S. 1 Bypass. Another exposure of the fault may be seen about 500 yards up Hazel Run on the east bank of the stream.

The fault trends N32°E and dips northwest at a steep angle. The age of the fault is not known, but an associated fault, the Fall Hill Fault, displaces Quaternary alluvium (Mixon and Newell, 1978).

Near the upstream exposure of the fault are good outcrops of augen gneiss of the Fredericksburg complex containing feldspar rich difles. A relatively unfoliated pluton can be seen some 200 yards upstream.

STOP. 3. Alum Springs Park belonging to the City of Fredericksburg, located about 1/4 mile south of the junction of Route 3 and U. S. 1 Bypass on the east side of Route 3.

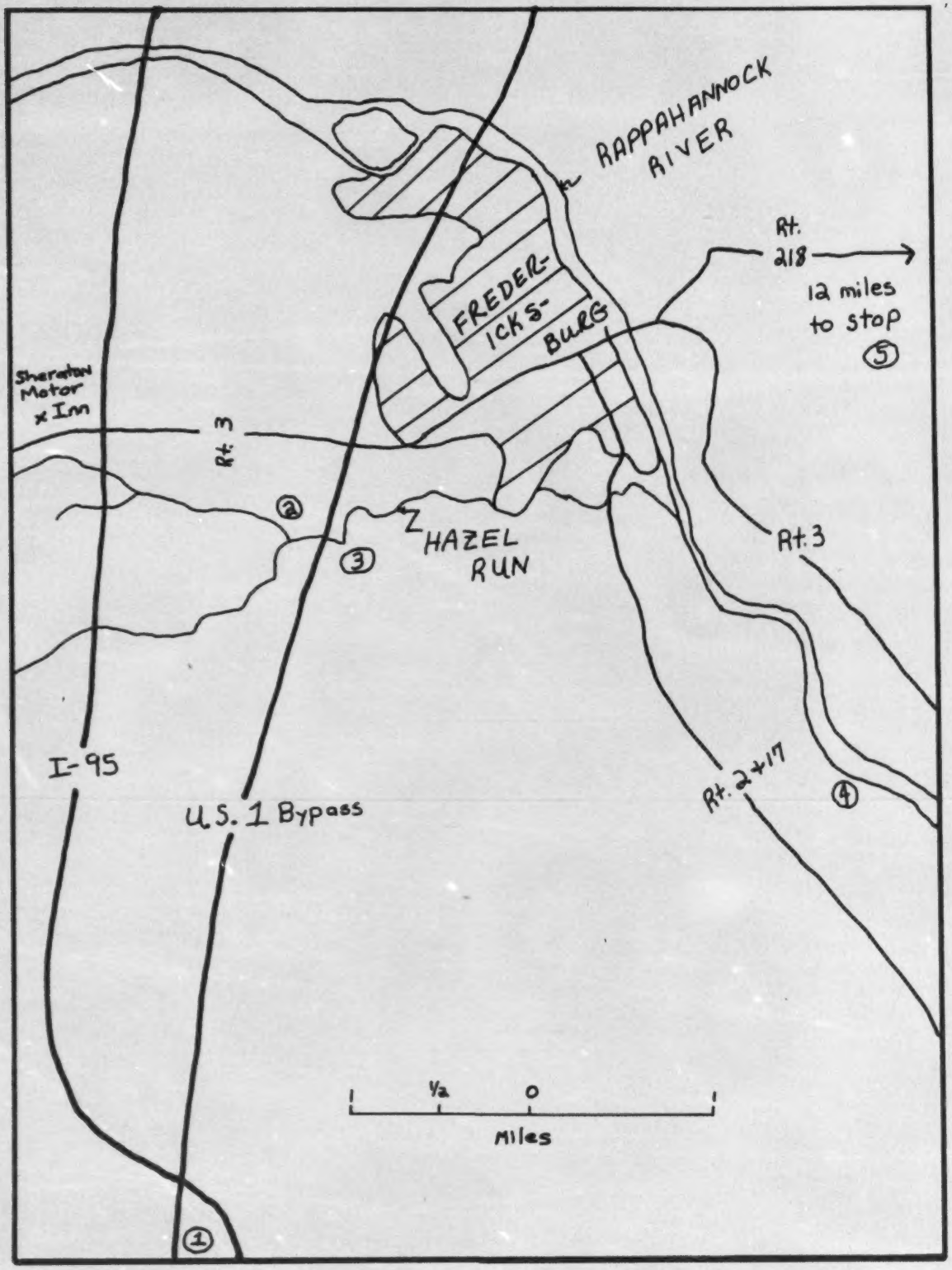

Fig. 1. Map of major routes and field stops in the Fredericksburg, Virginia area.

COMPOSITE STRATIGRAPHIC SECTION

Elevation (ft.)	Series	Formation	Lithology
140-135	Quaternary	Terrace Deposit	Two feet of gravels overlain by sand
135-102	Lower Cretaceous	Potomac Group	Dark, moderately sorted silt with angular quartz and with abundant micas
102-76	Lower Cretaceous	Potomac Group	Moderately sorted coarse sand with limonite cement and abundant plant fossils. Cross beds dipping mainly westward
76-60	Lower Cretaceous	Potomac Group	Poorly sorted feldspathic sand, locally indurated; with relatively high heavy mineral concentration. Cross beds dipping west and east.
60-50	Lower Cretaceous	Potomac Group	The dark green and red micaceous clay with little silt

STOP 4. Abandoned sand and gravel pit (formerly operated by Solite Corporation) two miles southeast of Fredericksburg on north side of Rts. 2 and 17.

A composite sample of sediment from this low, Rappahannock River terrace consists of about 20 percent gravel, 65 percent sand, and 15 percent silt and clay (personal communication, Ed Phillips, geologist, Solite Corporation, Richmond, Virginia). Boulders up to 4 feet in diameter occur sporadically throughout the deposit. The gravel fraction increases markedly downstream in the vicinity of the mouth of Massponnox Creek; this indicates that the gravel source is the "Upland Gravels" along this tributary.

STOP 5. Belvedere Beach on the Potomac River about 12 miles east of Fredericksburg at the terminus of Rt. 654; property of Mr. Oliver W. Besley.

Eighteen feet of drab, dark grayish-green, fine-grained quartzose and glouconitic sand (Aquia Formation), abundantly fossilferous in the lower seven feet. Among the vertebrate fossils found here are the sharks, *Odontaspis elegans and Otodus obliquus;* the skate, *Myliobatus copeanus;* the parrot fish, *Phyllodus toliapicus;* and a web-footed turtle, a water snake, and a giant crocodile, *Crocodilus antiquus.* More common are assorted snails and clams including *Turritella mortoni* and *Ostrea compressirostra, Crassatellites alaeformis* and *Anadara* sp.

Mr. Besley has collected large numbers of the vertebrate and invertebrate remains and has helped prepare the faunal list above. He is donating part of his fine collection to Mary Washington College and plans to show us some of it on the field trip.

ROAD LOG

Cumulative Mileage	Point to Point Mileage	
0.0		Leave parking lot of Sheraton Motor Inn.
0.1	0.1	Turn left (East) onto State Rt. 3
0.2	0.1	Exit Rt. 3 onto I95 South
4.4	4.2	Turn right onto U. S. Rt. 1 South
5.6	1.2	Turn left at County Rt. 755 (formerly Rt. 635)
5.8	0.2	Bus turnaround

STOP 1. HICKS BURROW PIT

Questions: How many formations present in pit? What is the nature of their contacts? What is the general environment of deposition of each? How would you go about establishing the age of these deposits?

5.8		Reboard bus and proceed north on U. S. Rt. 1 to I95 North.
11.5	5.7	Turn right and exit at State Rt. 3 East
12.4	0.9	Turn left to exit on U. S. Rt. 1 Bypass South
12.5	0.1	Turn right onto U. S. Rt. 1 Bypass
13.1	0.6	Pull right to park at Mary Washington Wayside

STOP 2. HAZEL RUN FAULT NEAR MARY WASHINGTON WAYSIDE.

Proceed by foot 200 yards west to first seen tributary of Hazel Run.

Questions: What is the evidence for faulting here? Are you sure it is a reverse fault? What sort of data would allow you to determine the age and the displacement on the fault?

Cumulative Mileage	Point to Point Mileage	
		Proceed up Hazel Run to contact of Potomac Group and Crystallines. Questions: Is the trend of the fault here similar to that seen earlier? Are dikes in the crystallines of more than one age?
		Return down Hazel Run and reboard bus.
13.4	0.3	Proceed South on U. S. Rt. 1 and turn left onto Twin Lake Drive. Road cut to right exposes Aquia and Calvert Formations.
		Turn around at Twin Lakes Drive and return to U. S. Rt. 1 Bypass
13.5	0.1	Turn right (north) onto U. S. 1 Bypass
14.3	0.8	Proceed to State Rt. 3 and exit east (right)
14.5	0.2	Turn right onto Greenbrier Drive
15.0	0.5	Proceed to parking lot of Alum Springs Park

STOP 3. ALUM SPRINGS PARK

Walk west across 70 foot terrace of Hazel Run to cliff exposures of coarse sand of Potomac Group. Three units may be seen from the stream to the cliffs.

Questions: What is the probable depositional environments of these three units? What is the source rock and direction of each? What is the orientation of the long axes of the plant molds and fragments? What do you make of this?

Proceed to the west end of cliffs and climb steps to bed of Civil War railroad. Proceed east to cut through section showing silt and sand of Potomac age and stream terrace deposits.

Continue east to pavillion for lunch.

LUNCH

15.5	0.5	Reboard bus and turn right (east) onto State Rt. 3
16.5	1.0	Turn right onto Kenmore Ave. and follow ancient channel of Rappahannock River to U. S. Rt. 1
17.0	0.5	Turn left onto U. S. Rt. 1
17.05	0.05	Turn right (east) onto Charles St.
17.3	0.25	Turn right onto U. S. Rt. 17 and proceed to unnamed road
19.3	2.0	Turn left onto "pit road" and follow road to its terminus at abandoned sand and gravel pit.

STOP 4. ABANDONED GRAVEL PIT

Walk into pit at edge of Rappahannock River.

Questions: How are these deposits different from the stream deposits expected here? Is there any evidence of estuarine circulation here?

Reclamation in these pits includes covering the base of the pit with the original soil cover. Thus, it is argued, some of the most valuable farm land in Virginia is only temporarily lost (during the time of mining). What do you think of this?

20.3	1.0	Reboard bus and return to U. S. Rt. 17
		Turn right (west) onto U. S. Rt. 17 and proceed to City Truck Route.
22.4	2.1	Turn left onto Truck Route 2 and 17
22.6	0.2	Turn right onto U. S. 17 and 1 and State 2 and proceed to State Rt. 3
23.1	0.5	Turn right (east) onto State Rt. 3
23.5	0.4	Turn left onto State Rt. 218 east and proceed beyond the first exit onto County Rt. 600 to the second one.
31.3	7.8	Turn left onto County Rt. 600 north
33.4	2.1	Turn right onto County Rt. 654
36.5	3.1	Proceed to terminus of County Rt. 654

STOP 5. BELVEDERE BEACH

Walk 100 yards upstream to excellent exposures of fossiliferous Aquia Formation.

Cumulative Mileage	Point to Point Mileage	
		Board bus and retrace routes as west on County Rts. 654 and then 600 to State Rt. 218 to State Rt. 3 and proceed west to Sheraton Motor Inn.
52.2	15.7	End of Trip

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THE CULPEPER BASIN OF THE TRIASSIC LOWLANDS OF NORTHERN VIRGINIA

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University of Maryland
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James V. O'Connor
U. S. Geological Survey

During the Triassic, early Jurassic period of time, 215 to 180 million years ago, the North Atlantic was opening up along a mid-oceanic spreading axis. Such divergent plate movement is believed to have been the cause of regional extension which opened up a large elongate rift valley system along the eastern seaboard of North America (Faust, 1975). Much like the rift valley system of East Africa today, this east coast rift valley system, called the Newark Basin, contained a succession of large elongated lakes (up to 11,000 km.^{2} in surface area) in more than a dozen structural basins, which were aligned with the regional trend of the Appalachian Mountains (see Fig. 1). The Culpeper basin is one of the structural trough depressions bordering the eastern front of the Appalachian Mountain System (see Fig. 1).

A generally accepted mechanism explaining the structural origin of these basins has been the formation of a large graben (up to 100 km. in width) later uplifted along its axis (Russell, 1878; Barrell, 1915; Woodworth, 1932; Sanders, 1963). According to this explanation the Newark Basin supergroup lies on the western limb of the arch and the New England basin on the eastern limb. A contrasting interpretation based on unconformities along an extension of the border fault holds that it is a simple downwarped basin (Faill, 1973). Sedimentary rocks originally deposited in the center of the graben were eroded and transported beyond their original outcrop belt as uplift took place. The extension of Triassic deposits through this uplifting mechanism has been referred to as the "broad terrane" hypothesis.

One of the major problems associated with this interpretation is that typical graben structures are bounded on both sides by nearly equal magnitude faults, but in the Newark Basin system such fault symmetry is not common. Lindholm (1978) proposes that structural faults controlling the basin's formation occurred in areas where foliation strikes approximately at right angles to the tensional stress. If the foliation dipped west, a west-dipping normal fault developed; if the foliation dipped east, an east-dipping fault formed. One requirement

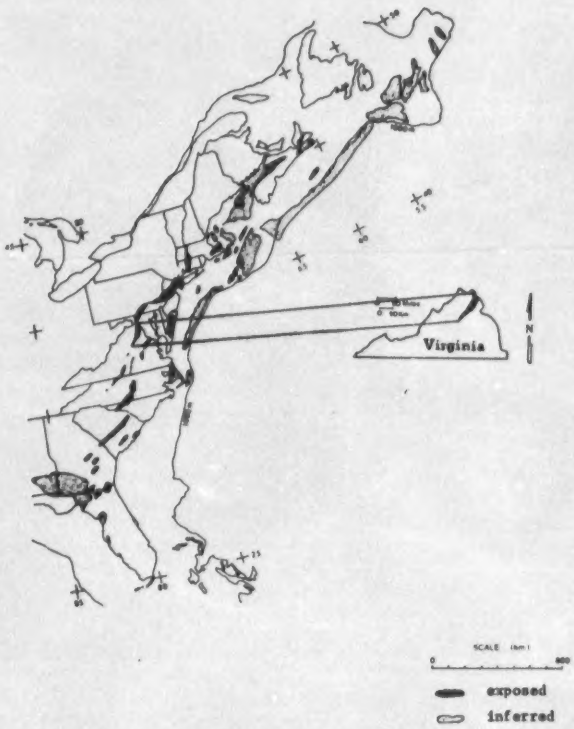

Fig. 1. Map of the Newark Supergroup basin locations. Dark areas are outcrop locations and stipled areas are inferred locations of sediment present beneath the Atlantic Coastal Plain.

for the formation of a major fault was a large area of foliation with uniform strike and dip. Where the attitude of the foliation was erratic the rock was not conducive to fault development (see Fig. 2) (Lindholm, 1978).

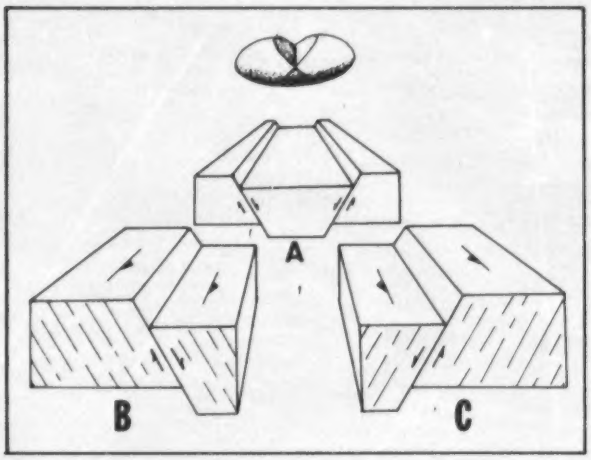

Fig. 2. Diagram showing graben structure bounded by normal faults. Strain ellipsoid at top acting on homogeneous rock material illustrates classic tensional stress. Block B has east-dipping foliation and facilitates an east-dipping fault. Block C has west-dipping foliation and facilitates a west-dipping fault. (From Lindholm, 1978)

Thousands of meters of sediments were deposited in the lakes, swamps and sand flats of the basins and later became lithified to form the brown and maroon rock that colors today's landscape. Such color and the relative absence of organic material indicate a wet-dry climate. Mudcracks, rain-drop impressions, local accumulations of coarse clastic sediments, and lens-shaped bedding of poorly sorted sands imply intermittent torrential discharges of water in equatorial like conditions. (Further substantiation for an equatorial condition for the environment of deposition comes from paleomagnetic data that indicate that the Culpeper Basin of Northern Virginia was near the earth's equator during the Triassic/Jurassic period of geologic time.)

Continental sequences over 10,000 m in thickness, known as the Newark supergroup, are preserved in the Culpeper Basin. This group has recently been redefined into the Manassas Sandstone, a mostly loose to semicompact sand and gravel; the Balls Bluff Siltstone, a limestone composed of silt size sediment (calcisiltite); and the Bull Run Formation consisting of chiefly brecciated limestone fragments in a matrix of red clay silt and calcite. A basaltic flow-bearing clastics member of the Bull Run Formation consists of greenstone, quartzite and limestone conglomerates, sandstone, shale and locally, coal and limestone (Lee, 1977) (see Fig. 3).

Since the last century, various fossils have been collected from the Newark Group in the Culpeper Basin. Russell (1892) and Roberts (1928) gave information on locations of fossil flora and fauna found in the basin. Excellent fish fossils have been collected from at least 30 localities being preserved in the varved layers that are interpreted as evidence for a history of major cycles of waxing and waning of the lake waters. The layers provide nearly a year-by-year record during the period when the lake in the basin was deepest (see Olsen, 1978). Dinosaur tracks are rare but the impressions and remains of the labyrinthodont amphibians and phytosaurs and other reptiles have been reported south of Leesburg at President Monroe's estate, Oak Hill, and at Dulles International Airport (see Eggleton, 1975). Although the diagnostic fossils have not yet been established for specific correlation with Triassic strata of Europe, encouraging results have begun to appear from comparative studies of the red beds of west Africa with the Triassic deposits of eastern North America (see Van Houten, 1977).

ROAD LOG

Cumulative Mileage	Point to Point Mileage	
0.0	26.0	Leave Fredericksburg, north on I-95 to Rt. 234W.
32.0	6.0	West on Rt. 234 past Prince William Forest Park (National Park Service) to Independent Hill.
34.9	2.9	Northwestward on Rt. 234 to Lake Jackson-Occoquan River. (Footing of dam is on Occoquan adamellite (a granite containing equal amounts of orthoclase and plagioclase with more than 2% quartz). Exposure of eastern border fault evident in saprolite at this location.)
35.9	1.0	Cross Rt. 28, continuing on Rt. 234 (Grant Ave. in downtown Manassas).
37.9	2.0	Continue on Rt. 234, crossing under I-66 passing Northern Virginia Community College. Turn right.

STOP 1: MANASSAS NATIONAL BATTLEFIELD PARK VISITOR CENTER (Rt. 234—GAINSVILLE QUAD.)

Historical Notes: The first major battle of the Civil War occurred on July 21, 1861 (First Manassas or First Bull Run) where the Orange and Alex-

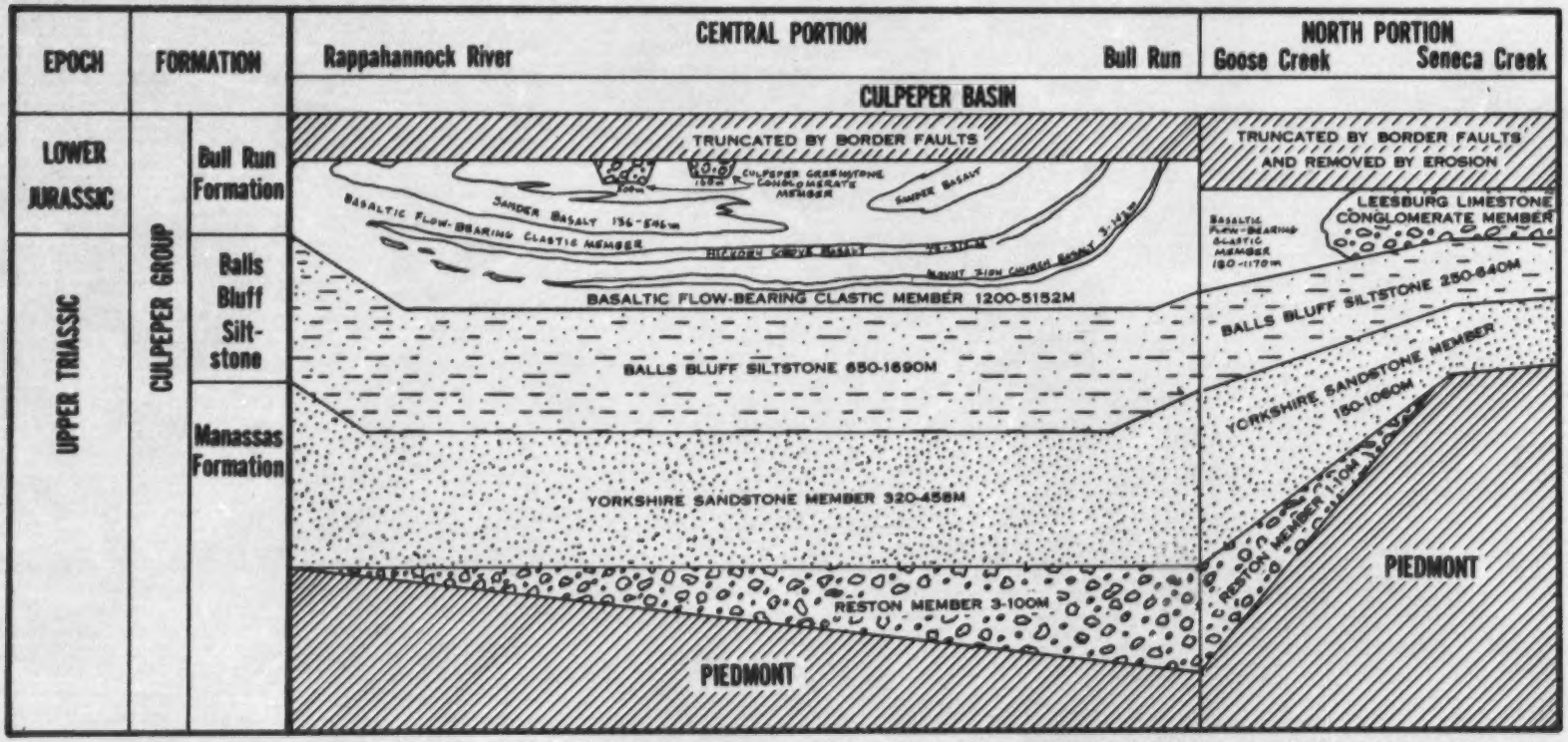

Fig. 3. Stratigraphic correlation of the Culpeper Basin (north central portion) After K.Y. Lee

andria Railroad met the Manassas Gap Railroad. This junction was the controlling factor in the staging of the first major battle of the war. This is also the battle site in which Stonewall Jackson received his nickname.

The Southern Army set up along the banks of Bull Run at the six fords and bridge that crossed the stream. The July day was a typical Washington hot summer day; Confederate sentries noticed the rising dust clouds as Federal troops moved from Centerville. The wispy dust plumes turned to dense clouds. The signal men also noticed that the bayonets and brass cannons glistened in the sunshine, plotting out the advancing Federal column. The Federal troops also found that upon arrival at Sudley Ford and Sudley Springs that the water in Bull Run was refreshing and the spring water quenching to drink. This setting was not conducive for fighting, thereby giving the Confederate army a chance to have more troops arrive by train, balancing the number of troops on both sides. Use of the terrain by the southern forces was a key factor in the overwhelming victory. Over 3500 were killed or wounded in this first skirmish. Although the second battle of Manassas or Bull Run was not as famous (August 29-September 1, 1862), over 19,500 were killed or wounded as Jackson surprised the Union forces from behind the Sudley railbed which is northwest of the Visitor's Center. The present tracks of the Southern Rail still follow the two previous railroads.

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
39.8	1.9	Return to Rt. 234, proceed north, turn west (left) onto Rt. 29-211, proceed 1 mi. to top of hill.

STOP 1b. RED AND GREEN UNITS OF THE BALL'S BLUFF FORMATION (RT. 29-211 WEST BOUNDARY OF PARK: GAINSVILLE QUAD.)

This outcrop of highly fractured, weathered thin bedden shales is important because of the color changes in the strata. The change from red to green and the small pieces of plant stems (rare) are clues to the rapid change in the micro-environment. The beds are tilted to the west, and the environment of deposition probably is lacustrine or paludal. The more resistant beds have a higher sand content. The Ball's Bluff Formation in this location is estimated to be almost 2,000 meters thick.

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
41.6	1.8	Retrace route to 29-211/234 junction, proceed east on 29-211 past Stone House .8 mi. to Stone Bridge.

STOP 1c: OLD STONE BRIDGE (RT. 29-211: GAINSVILLE QUAD.)

This pre-Civil War bridge was the site of some of the fiercest fighting in the first battle. The brownstone bridge was destroyed (see archival photograph below) but was rebuilt in the beautiful architecture possible with the sculptural potential of the stone. The east bank exposures under the bridge and in Bull Run are part of the Ball's Bluff Formation (Lee) or the Bull Run shale (Roberts). Close attention should be paid to the westward dip and the joint sets. The small whitish specks are calcareous and are important in establishing the environment of deposition.

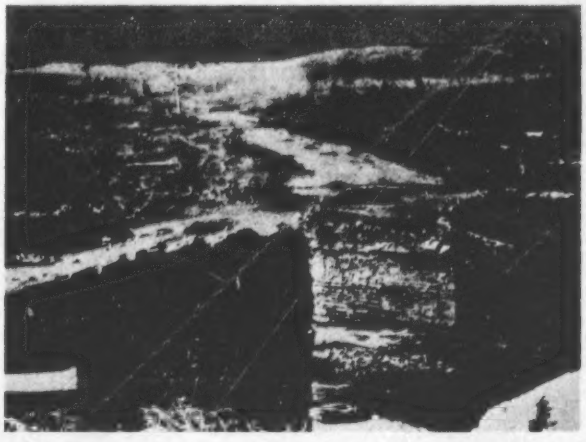

Fig. 4. The ruins of the Stone Bridge over Bull Run, from the east. Here began the first Battle of Manassas. Wartime photograph, courtesy National Archives.

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
46.2	4.6	Return to Rt. 29-211, turn east approximately .6 mi. to Centerville Quarry on right.

STOP 2. CENTERVILLE DIABASE QUARRY (LUCK COMPANY, INC.) (RT. 29-211 WARRENTON TURNPIKE: MANASSAS QUAD.)

NOTE: Hard hats must be worn at this stop.

This particular quarry has been in operation since 1926 and has a variety of names: Bull Run Quarry (from its location in the town of Bull Run); Fairfax Quarry from its former owner (Fairfax Quarries, Inc.).

This particular quarry has yielded many mineral crystals for the Smithsonian Institution, university geology departments, as well as collectors. The diabase is quarried primarily for road construction aggregate as well as limited use for rip rap. The intrusive structure has been intruded into the surrounding Triassic shales and is believed to be a lopolith or an "h" shaped intrusive where two west dipping sills are connected by a vertical dike.

It is composed basically of aggregates of fine-grained (less than 1 mm) white plagioclase feldspar and greenish black pyroxene, which accounts for its characteristic peppered appearance. Aplite veins, light colored streaks consisting almost purely of albite, with some admixed quartz, can be seen running parallel to the joint systems. These contain minute miarolitic cavities, so they are easily attacked through chemical weathering. The aplite veins range in size from 1 to 6 cm. Diabase is typically well jointed in three directions and an excellent example of this can be seen by going through the tunnel under Rt. 29-211. The east wall is one large joint plane, forming a smooth vertical face 60 feet high. Other smaller joints intersect it at roughly right angles. The joints are the weakest part of the rock and consequently first to weather. The first signs of this are the thin films of diabantite-type chlorite along them.

Mineralizing hydrothermal solutions also tended to follow joints and deposited a variety of minerals, mostly zeolites and their relatives, along with some sulfides and oxides. During the Springs of 1953 and 1967, large veins of pinkish-white apophyllite crystals, which ranged up to 15 cm, implanted on apple green prehnite were uncovered. Many of these specimens are now in museums the world over, and the finest apophyllite crystal in the world, found in 1967, is at the Smithsonian.

The Vulcan Quarry and the Bull Run Stone Company both operate in the same structure which highlights Linkskold's "h" hypothesis.

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
48.2	2.0	Proceed east past I-66 to junction of Rt. 29-211 and Rt. 28 in Centerville. Turn north on Rt. 28.
49.7	1.5	Pass over I-66 and Rt. 620 on left and Rt. 657 ahead on right. Pass over bridge from Big Rocky Run and pull off into parking area on right.

STOP 3: YORKSHIRE SANDSTONE MEMBER OF THE MANASSAS FORMATION (RT. 28 AT SW BANK OF BIG ROCKY RUN: MANASSAS QUAD.)

The Manassas Sandstone of Roberts (1928) has been used as an important building stone (called brownstone) in Baltimore, Washington and Richmond. Although its true color is gray, most recognize it by its maroon color that gets darker as it weathers. The ratio of quartz to felfdspar and mica plus the cementing agents determine the better quality resistant stone. Because of the resistant nature of the sandstone, it forms many cliffs along the stream banks. The variations in strata may give clues to the depositional history, especially where cross-beds, laminae, and other primary or secondary sedimentary features are preserved. Although the better outcrop is around the corner on Braddock Road, the nature of the heavily travelled blind curve makes it unsuitable for a large group. Note should be taken of the beds, the compaction, coarseness of the grain size, and features.

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
55.2	6.5	Proceed north on Rt. 28 toward Dulles Access Road, crossing Rt. 50. Walk down ramp to outcrop. (Bus will proceed to Airport and return on access road east.) Proceed on foot to Reston Avenue.

STOP 4: HORSEPEN RUN REDBED EXPOSURE (SOUTH OF RAMP FROM DULLES ACCESS ROAD TO RT. 28-S: HERNDON QUAD.)

Because of Dulles Airport, this realigned stream has eroded out a good sequence of the Ball's Bluff Formation (Lee). The beds consist of interbedded

calcareous siltstone, shale, thin arkosic sandstone, and shale with limey nodules. Bedding and jointing are well illustrated at this outcrop. Chemical analysis of the airport well water indicates high amounts of Fe, S, and CO_3. The leaching of these elements and compounds from the Triassic bedrock and their migration via the regional joint system probably accounts for this.

The construction of Dulles Airport created a whole new drainage for the area. Comparison of the stream systems before and after yields valuable insights into stream alignments in relatively flat areas. The bedrock is currently closer to the surface because the soil and residuum (weathered parent material) were largely removed or redistributed during construction of the airport complex. Eggleton reports that a disarticulate phytosaur skeleton was discovered and identified during the construction at the airport.

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
57.2	2.0	Proceed north on Rt. 602 to Rt. 7, passing Rt. 606 and 602 junction noting clay-balls on S.E. side (informal stop, time permitting) about 100 m south of intersection of the Baron-Cameron Avenue and Reston Avenue.

These ellipsoidal clay-balls are molded and abraded chunks of clay from stream banks by shooting flow probably during early Pleistocene. Scattered quartz granules, some quartzite pebbles contained in the clay, commonly mantles older rock masses. The size of the clay-balls chiefly depends on the amount of clay material that fell into the turbulent water as well as the amount of clay that was accreted during sedimentation. Concentric and convoluted structural features of reworked Reston sand grains and rock fragments are seen surrounding the clay-balls.

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
63.3	6.1	Continue north on Rt. 602 and west on Rt. 7 toward Leesburg. Make first left as you start to descend hill after first set of lights on Rt. 193. Proceed .15 mi. to junction of Sugarland Road.

STOP 5: EASTERN CONTACT: RESTON CONGLOMERATE AND THE PIEDMONT (JUST WEST OF RT. 602 (RESTON AVE.) ON THE W & OD ABANDONED RAIL LINE. VIENNA QUAD.)

(The local utility company (VEPCO) has just given the land rights for the old rail line to the Northern Virginia Park Authority which intends to make the right-of-way a bike trail.)

At this outcrop and a few others in a straight line from the USGS National Center north to Rt. 7, good temporary exposures document the eastern edge of the Culpeper Basin as the Triassic sediments rest uncomformably on the Piedmont crystalline basement of gneisses and schists. The unconformity and border zone is complicated by the faulting (Milton, Froelich) evidenced along this small portion. Lee has defined the basal unit as the Reston member of the Manassas formation. This base is marked by a conglomerate of coarse schist and quartz pebbles, and coarse quartz-feldspar sandstone (arkose). There is abundant muscovite in the unit and the hematite-limonite coatings are also important. The unit is described as fluvial channel fill.

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
64.5	1.2	Retrace route to Rt. 7, turn west on Rt. 7 descending into east limb of graben. Note extensive red bed exposures crossing Sugerland Run. Proceed west to junction of Rt. 7 and Rt. 28. Turn right onto Rt. 808, parking in church parking lot.

STOP 6: EASTERN BORDER CONTACT BETWEEN THE PIEDMONT PLATEAU AND THE TRIASSIC-JURASSIC LOWLAND IN THE DRANESVILLE SECTION SOUTH OF RT. 7 (SENECA QUAD.)

This series of gutter trenches and roadside cuts shows a unique picture of the eastern edge of the Culpeper Basin where the Culpeper Group of the Triassic-Jurassic Lowlands are in fault contact with the Peter's Creek Formation (Drake) of the Piedmont Province. Unlike most of the eastern border where a regional unconformity is recognized and mapped, this locality clearly shows where several normal faults are present. Three faulted structures were outlined by Froelich: a horst of Piedmont schist within the Triassic rock; a graben of Triassic rock within the Piedmont schist; and

Reston conglomerate uplifted against the younger Triassic sedimentary rock of the Manassas Formation. These small normal faults trend to the northeast, paralleling a topographic lineament and an aeromagnetic lineation (Blanchett) which is believed to indicate a larger fault zone along the eastern edge farther to the South (Wier, Koklemann—personal communication). The precise age of these faults is unknown at present; they are either syn- or post-Triassic. Saprolite is a term used to describe decayed metamorphic rock that has not converted to soil. Both the faults and the schistosity of the basement units are well preserved in the exposed saprolite. The saprolite developed on the schist is approximately 30 m in depth (Froelich) and yellowish-red to reddish brown in color. The Piedmont Glenelg soils develop on this saprolite. These well-drained soils are dark brown-gray silt loams and most productive for agriculture. The thin, well-drained soils that develop on the Triassic sedimentary rocks are the Penn silt loams. These soils are developed from the residuum (on the average 1 meter thick). The characteristic deep reddish-brown color of these soils is easily recognized in the field.

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
69.5	5.0	Retrace to Rt. 7, proceed west to junction of Rt. 7 and Rt. 28.

STOP 7: THE OVENS (JUNCTION OF RT. 7 AND RT. 28 AND RT. 7 & Rt. 808—STERLING QUAD.)

This stop is a classic textbook example of contact metamorphism. There are three sub-stops at this intersection. First is the bank of the small stream on the northwest side of the intersection where red beds of the Ball's Bluff formation are well exposed westward to Broad Run. Of particular interest is the epidote nodules that weather out. Where did the epidote come from? Epidote is $Ca_2(Al, Fe^{+++})_3(SiO_4)_3(OH)$. Measure the strike and dip of the red beds. Is this traprock a dike or sill? The linear ridge across the intersection is diabase and it structurally controls the streams on both sides and serves as a distinct topographic high. The third stop in the traverse is the zone of metamorphism. Exposed in the same stream valley as the red beds is the "baked red beds" with their typical black-gray color. Can you work out the relative age of the three rock units? This baked zone is the contact aureole of the trap rock. Knowing the chemistry of the igneous rock and the sedimentary red beds, can you explain the color and chemistry of the metamorphic zone?

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
73.5	4.0	Retrace to Rt. 7, proceed west passing xerox training center and Goose Creek. (Park on shoulder of road after crossing Goose Creek.)

STOP 8: ABANDONED STATE AGGREGATE QUARRY-GOOSE CREEK & RT. 7 (NW SIDE OF RT. 7 & GOOSE CREEK: LEESBURG QUAD.)

With the addition of two more lanes to Rt. 7, the rubble from the road cut was dumped into the old quarry. Detailed studies and photographs are in Toewe's (1966) report on the Leesburg Quad. Although a stratigraphic section was measured (Toewe-Appendix II) and photo (pg. 9) is included, there is current controversy over the rock types. Toewe's analysis of the pyroclastic rocks gives a layered sequence of felsic tuffs—andesite, trachyte, and dacite. Recent mapping has suggested that the units are spotted hornfels with the evidence for this based on a contact aureole of the Belmont stock which baked the Ball's Bluff and Bull Run formations. The normal fault mapped by Toewe from Belmont through the Goose Creek quarry still is observable in the back wall of the filled-in quarry and has a structural influence on Goose Creek. The normal fault with its wide fault gouge zone has also added to the metamorphism of the area. Numerous slickensides are found and the mineralogy of the slickensides is worth collecting (epidote, calcite, magnitite). Dendritic patterns of some minerals may also be collected. Best collection sites are at the road cut on Rt. 7. Rogers (1928) describes copper minerals in the area produced by hydrothermal alteration. Large nuggets of native copper weathering to malachite were recently found at the road cut. (The copper occurrence does not weaken either stance on the local rock type.)

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
76.4	2.9	Proceed west on Rt. 7 to Rt. 15N bypass. Proceed to Rt. 837 (Ball's Bluff Cemetery Road). Turn left to Rt. 15, parking on shoulder of road.

STOP 9: LEESBURG CONGLOMERATE MEMBER—BULL RUN FORMATION (LEE) (RT. 15 NORTH OF LEESBURG—SOUTH OF BYPASS: WATERFORD QUAD.)

The Leesburg conglomerate is primarily a limestone conglomerate in its type locality but changes north and south as the source areas change. These western border conglomerates are isolated units and are labeled as fanglomerates to demonstrate their origin. The rock was quarried for aggregate, lime, and building stone. As a building stone it is referred to as "Potomac Marble" or "Calico Marble" in the literature. The polished pillars in Statuary Hall of the U. S. Congress are made from this rock.

The size, shape, and orientation of the pebbles and cobbles indicate an active history: syn- and post-deposition. The matrix and brecciated granules also recount a variety of different movements. The role of the movement of the border fault is a key to the depth, thickness, and westward dip of the unit.

Because of the limey nature of the unit, some pseudo-karst topography is visible as well as unique types of vegetation.

Recently Lindholm and his students have developed a new model based on the plunge and erosion of the eastern limb of the Catoctin fold to explain the provenance and placing of the different rock types included among the border conglomerates (see Introduction). The border fanglomerates from north to south or youngest to oldest parent material are dolomite, limestone, quartzite and greenstone.

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
80.9	4.5	Proceed north to Bypass, taking Bypass south to Rt. 15 (south of Leesburg). Take Rt. 621 south to Evergreen Mills at Goose Creek.

STOP 10: EVERGREEN MILLS AT GOOSE CREEK: PYROCLASTICS OR BAKED RED BEDS? (RT. 621: LEESBURG QUAD.)

Toewe has mapped this area as a pyroclastic unit similar and connected to the unit at Rt. 7 and Goose Creek. Beside a small abandoned quarry, this area also has the diabase (Belmont stock), and a small normal fault. This area is a zone where the Leesburg conglomerate member of the Bull Run Formation, the Ball's Bluff Formation (baked?), and the diabase are all converging. On the north side of the river the conglomerate is metamorphosed. The exposure provides an opportunity to investigate the controversy over the sequence of tuffs versus a sequence of baked red beds (or possible combination of both). Lee (1978) has mapped this zone as the contact aureole of baked red beds in contact with the diabase stock in his geologic map of the Arcola Quad. to the south. The sandstone, shale, and conglomerate do not bake the same way because of chemical variations. Heat differences generated by a large pluton versus the heat generated by a dike or sill are important in understanding the thermal variability in chemical alteration of existing sedimentary units. Unlike the Rt. 7 quarry, this sequence in the roadcut is available for research. Since most other Triassic-Jurassic basins (including the African basins) have tuff units, this occurrence in the Culpeper Basin could well be a significant exposure in unraveling the basin's tectonic history and its relation to other basins. (For correlation studies see Van Houten, 1977.)

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
83.2	6.8	Proceed on Rt. 625 (note map # not Virginia highway #) to Rt. 50. Park in Mt. Zion Church parking lot.

STOP 11: MT. ZION CHURCH BASALT FLOW OF THE BULL RUN FORMATION (RT. 50 IN THE ARCOLA QUAD.)

This exposure is the type locality for the oldest or lowest Jurassic basalt flow of the three in the redefined Bull Run Formation (Lee, 1977). The flow is described as a dark gray aphanitic to fine texture, sometimes porphyritic and sometimes vesicular especially in the upper zones. The flows are crescent in shape with horns toward the border fault. The younger flows, in sequential order, are the Hickory Grove flow and the Sanders basalt. (How these units correlate to the three flows in Connecticut or New Jersey has not yet been determined.)

ROAD LOG (CONT'D)

Cumulative Mileage	Point to Point Mileage	
86.2	3.0	Proceed on Rt. 50 west to Rt. 15. North on Rt. 15 to Oak Hill.

STOP 12: ALDIE QUARRY AND PRESIDENT JAMES MONROE ESTATE (PRIVATE PROPERTY) AT OAK HILL. (RT. 15: ARCOLA AND LEESBURG QUADS.)

The Jurassic dinosaur footprints from the Culpeper Basin are exposed in the patio stones of the formal gardens of Oak Hill which was the home of President James Monroe. The stone was quarried from the property in the twenties as part of the historical restoration. Most of the three-toed prints are from carnivorous dinosaurs (determined from the sharpness of the claws). The pantry within the house still has well-preserved positive and negative prints. The smaller impressions are believed to belong to Anchiosaur and the larger prints to an unnamed carnivore. Current investigations are studying the possibility that they correlate to the Rocky Hill, Connecticut tracks. The Aldie or Oak Hill Dinosaur Quarry is located on the north side of Little River just west of Rt. 15 and is the type locality for part of the Bull Run Formation (Lee, 1977). The unit is sandwiched between the second (Hickory Grove) and third (Sanders) basalt flows. Toewe (1966) describes these units as diabase in his Leesburg geological map. Many sedimentary features and bedding planes are well exposed in this small hand-operated quarry, long abandoned. Samples of basalt flow too may be collected on Rt. 15 between Little River and the mansion entrance at an easily recognizable outcrop. Flow three is exposed just west of the dinosaur quarry at an aggregate pit. However, we found it is usually guarded by a hefty bull—go gently or quickly!

General Information on Fossils

Fossils within the Culpeper Basin are few and rare but they do exist. Most fossils are bits and pieces of flora or fauna with some traces such as footprints. Only recently has a concerted effort been applied to seek out the data and restudy it (Olsen). While most of the earlier studies were on coal plant flora and fishes of the Richmond Basin, recent studies are now conducted in the Culpeper Basin. Schaeffer (1978) and Olsen (1978, 1979) have studied the Midland and haymarket fossil fish remains. (The Haymarket-Thoroughfare Gap Zone has succumbed to urbanization at present.) The Culpeper fish remains are *Redfieldius gracilius*. They range from 30 mm to 164 mm long. The first few collected are at the Smithsonian. Other samples are at the museums in Cleveland, New York City and New Haven. *Redfieldius* had become an exclusively Liassic (lower Jurassic) taxon with a wide geographic distribution (Schaeffer, 1978). The fish are usually found in fissile-flaggy, gray-black, microlaminated, pyritic carbonaceous or calcareous shale, siltstone or argillite indicating a H_2S rich reducing environment.

Lignitized plant stems are common in the green sedimentary units especially in the Bull Run Formation clastics. Plant stems and pieces (it's almost impossible to tell species) occur in many of the lacustrine or fluvial beds in the Manassas area.

The dinosaur footprints are now dated at Jurassic based on the stratigraphic sequence between the basalt flows. The Aldie toe prints are too well-weathered to compare accurately to the Rock Hill, Connecticut tracks (Lull, Ostrom).

A phytosaur skeleton plus small pelecypods and ostracods were discovered in the airport construction (Eggleton) (Stop #4).

The Smithsonian plate showing the recreation of the Aldie pit during the Triassic-Jurassic periods is a model drafted from the front porch of Oak Hill looking North to the Quarry. It is also the mural in the Mesozoic Hall at the Museum.

Fossils in the Basin are rare so that all findings should be reported to the appropriate science research group in the area.

ROAD LOG (CONT'D)

Proceed on Rt. 15 south to Rt. 234, left on Rt. 234 to I-95 to Fredericksburg.

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